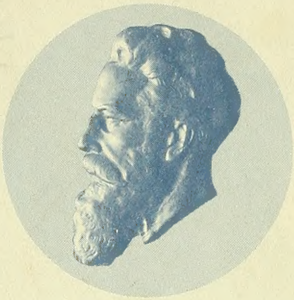

AN INTERNATIONAL SYSTEM

OF

ELECTRO-THERAPEUTICS:

FOR STUDENTS, GENERAL PRACTITIONERS, AND SPECIALISTS.

BY

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AND

THIRTY-EIGHT ASSOCIATE EDITORS.

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PREFACE.

Dr. de Watteville, in the preface to his second edition of that remarkable work on "Medical Electricity," says: "There are several considerable practical difficulties which will no doubt—at least, for some time to come—prevent electricity from becoming really popular with the medical profession. Foremost stands the absence of any theoretical and practical teaching in our schools; it is the object of this little book to supplement this want in some degree. Next comes the question of the apparatus required, which kind is the best, where to obtain it, and how to keep it in working-order?" Professor Forbes, writing in 1888, says, in his first lecture on electricity: "The work of the philosopher studying the phenomena of nature is accomplished by the aid of either observation or experiment. In the science of astronomy we can only wait, watch, and observe the signs which nature makes to us, and interpret the language in which she speaks. In the realm of electricity, on the other hand, we cannot depend much upon observation, and it is only in the laboratory, by patient experiments, that most of the secrets of electricity have been evoked. The highest delight of the true philosopher is in seeking out new facts, and the chief charm in electricity, to the true student, is in grasping the innumerable phenomena which are presented to his senses, and in co-ordinating and arranging these facts until he finds that a few general laws govern all the diverse forms under which the protean agent manifests itself."

Some interesting suggestions regarding the future of electricity are made in the new *Fortnightly Review*, by Prof. William Crookes, who was lately President of the Chemical Section of the British Association. Prof. Crookes is willing to believe that people may be seen telegraphing to each other without the use of wires. Two persons a mile apart may, in his judgment, have electrical machines so attuned to each other that they may converse with no other medium of communication than the air. Unlike a ray of light, an electrical vibration of a yard or more in length will go through a wall or heavy fog. Experimenters at present are able to generate electrical waves of this length and of any desired greater length. It is possible to refract some of these vibrations through suitably-shaped bodies, acting as lenses do for vibration of light. An experimenter at a distance could, with a properly-constituted instrument, receive these rays, and, by the use of a concerted code, carry on a conversation. What would be required would be more-certain means of generating waves of sufficient length to go through a house or a fog,—that is, of a yard or upward,—more delicate receivers which would respond to certain wave-lengths and would not respond to others, and

means of darting electrical rays in any special direction. This having been accomplished, two persons, living within the radius of sensibility of their instruments, and having decided on their wave-length, could communicate by timing the impulse to produce long and short intervals on the ordinary Morse code.

But might not anybody between the radius know what the two were saying? That, suggests the ingenious and sanguine professor, might be got over in two ways. If the position of the two instruments were known, the electrical rays could be converged on the receiving instrument and would go nowhere else. If, however, the two persons were moving about, they might agree upon a wave-length—say, fifty yards—which the instrument would be sensitive to and dull to others. As electrical waves may be thousands of miles in length, it would not be likely that other instruments would be attuned to this particular wave-length. Or, for that matter, the two friends might have recourse to a cipher. The professor asserts that this is no impossible and impracticable fancy, that even now telegraphing without wires is possible within a radius of a few hundred feet, and that, some years ago, he assisted at experiments when messages were sent from one part of a house to another without a connection wire, by precisely the method here indicated.

In these three excerpts, from the writings of men who are the acknowledged authorities in electrical science, we have presented some very serious and most entertaining facts:—

1. The necessity of special teaching in medical schools.

2. The necessity of a proper knowledge of physics, so that we may develop *original* work in our laboratories.

3. The strides that electricity is making in the arts.

If electro-therapeutics is to be placed upon a firm basis it must be practiced by thoroughly competent physicians. Such competency does not consist in bedside experience alone, nor in clinical observation, nor in acuteness of diagnosis; but he who would make this branch of medicine a specialty must know very much of the nature of the energy that he is using, as well as of the laws which govern it. In this connection it is my privilege to draw attention to the laborious work of my master, Apostoli. What he has done for the cause is not to be measured by sounding words. He is known and honored wherever electro-therapeutics has a following. Those who know and respect him, those of us who have had the privilege of a personal association with him, should see to it, both for the sake of the master who taught us, as well as for the sake of the science that we profess to admire, that we second him by original research and inquiry. In such wise only may we hope to give satisfactory answers to the many conundrums that are thrust upon us constantly by those who doubt the accuracy of our statistics. This can be done thoroughly only by following closely the trend of modern scientific research, and in fortifying ourselves with a thorough knowledge of

all that relates to the physics of the subject; in using this word physics I mean also to include physiological chemistry. Chemism, it is claimed by many, is simply a manifestation of a difference of electric potential of the molecule by which combinations are formed. Dr. W. J. Morton, of New York, one of the associate editors of the "System," has written a masterly thesis on "Protoplasmic Electric Centres in the Human Body." His theory is an ingenious one, well worked out and plausible. If future consideration of his ideas shall give them a stamp of exactness, we may arrive at last at a perfect understanding of the current to be used in treating disease from the stand-point of its electric potential. The study of the resistance of the human body, as suggested by Professor Houston, is also an important question to bear in mind. This study of electricity, as difficult and scholarly as any, can only be discussed and argued by those whose training has been such as to give them the right to be heard. Such discussions as these are always valuable, but the vagaries of sciolism should never be given the compliment of a hearing.

W. S. Hedley, writing to the *Lancet*, says: "The high-frequency furore has evaded the field of physiology and even that of electric therapeutics. It is possible and probable that on subsidence it may leave behind it results of solid and lasting value. It is conceivable even that our present electrical methods are on the eve of revolution, and that currents of high frequency and potential may eventually displace the three conversational forms of current ordinarily used in medicine. In the mean time the physician must keep an open mind—a 'level head.' His attitude must be that of inquiry, tempered, perhaps, by a wholesome tinge of skepticism. He must try to make good his way as he goes, and decline to be hurried along in an excited rush over ground that is, at best, but very insecure. He must often pause to steady his mind and question himself as to the 'what' and 'how' and 'why.' The 'what' is briefly this: It is well known that certain currents of high frequency (500,000 to 1,000,000 or more alternations a second), strong enough to light lamps, which, with ordinary frequency require currents that are dangerous to life, may be passed through the human body without producing any very appreciable effects in the way of sensation or neuromuscular phenomena in the shape of contraction. M. d'Arsonval, who, more than any one else, had experimented in this direction, states further: (1) that tissues traversed by such currents become rapidly less excitable, and that an analgesia lasting from one to twenty minutes is produced at the point of penetration; (2) that the vasomotor system is strongly influenced, as is shown by the fall in blood-pressure registered by the manometer in the carotid of a dog, or by the Marey sphygmograph in a man; (3) that on the continued application of these currents the skin becomes vascular and perspiration follows; (4) that animals submitted to the action of such currents show an increase in the respiratory combustions, as seen by examining definite quantities of

blood by the usual physiological methods; (5) that they have an influence on certain micro-organisms, as shown by their action on the pyocyanic bacillus (discoloration of blue pus); (6) that the body may be submitted to the action of such currents either by passing them directly through the tissues or placing the tissues, or the whole body, in the interior of a solenoid (without contact with it). This latter method he calls 'auto-conduction.'

"In connection with these observations he mentions two hypotheses: (1) that the current, on account of its enormous frequency, passes by the surface of the body as such currents are known to do with other conductors, and (2) that the sensitive and motor nerves are so organized as to respond only to vibrations of a definite frequency, in the same way that the terminations of the optic nerve are 'blind' for undulations of the ether of a period less than 497 billions per second (red), or more than 728 billions per second (violet). He rejects the surface theory so far as the animal body is concerned, and, though he passed currents of 3000 milliampères, he explained their harmlessness by 'absence' of excitation, or, rather, on the hypothesis that these currents exercise, on the nervous centres and muscles, an inhibitory action of the kind studied by Dr. Brown-Séquard; and he considers that this inhibitory action is shown by some of the phenomena above described.

"In this country the harmlessness of such currents is generally explained by the fact that there is virtually no current-strength (ampèrage). In the *Lancet* of December 24, 1892, I detailed some experiments with comparatively low-frequency currents which seem to point in this direction. In the *Electrical Review* it was pointed out that in all high-frequency experiments the current-strength is probably very small, owing to its being 'whittled down' by the various transformations to which it had been subjected.

"In the *Philosophical Magazine* of February, 1893, Mr. Campbell Swinton offered an explanation of the lamp-experiment which is now well known, which has been freely reproduced in the medical and lay press, and which is now, I think, the explanation most generally accepted.

"Attempts to form an opinion on such points may be assisted by reasoning of the following kind: Since efficiency varies with the square of the frequency, and since currents of high frequency must have high voltage for conducting the current, it follows that, to obtain an exceedingly small current of high pressure and high frequency, great power is required to produce it. Supposing that a current whose initial energy is as large as 2 ampères at 200 volts—*i.e.*, about half an electrical horse-power—is transformed up to 100,000 volts, the resulting current-strength (ampèrage) cannot be more than 0.004 ampère (4 milliampères). Now, if arguing from the initial energy, one begins at the other end, and takes the amount of work done at the terminals as the basis of reasoning, it occurs to me that a better and more definite point of departure is

obtained. What is the actual work done by a current of this kind as it escapes from further manipulation at the terminals of high-frequency coils? I place a five-candle lamp, which, on ordinary circuit, glows bright-red with 250 milliampères at 10 volts, between the terminals of the apparatus, and find that here also it is brought to the same degree of redness. I then substitute my body for the lamp by holding in my hand two copper cylinders. On turning on the current no muscular contraction or sensation, beyond a slight warming effect under the electrodes, is perceived. After breaking circuit there is, perhaps, a slight deadening of the ordinary cutaneous sensibility over the same area.

"Using a half-crown as an electrode on the forearm, there are no efforts beyond the above; using a shilling in the same way, there is a slight pricking effect; with a six-penny piece this becomes more marked, and with a three-penny piece painful. I am, therefore, in possession of two facts. In the first place I have applied to my body, through the area of the three-penny piece, a current which would bring to a red glow a lamp requiring, with a low-potential-current circuit, 250 milliampères and 10 volts (2 to 5 watts). Was I, therefore, passing such a current through my body? Taking my body out of circuit, I approximate the terminals until within sparking distance of each other. This distance measures one centimetre. Turning to de la Rue and Müller's sparking-table, I find that every spark-gap requires a pressure of 9000 volts to overcome it. But the total energy required to glow the lamp is 2 to 5 watts; therefore, the current-strength will fall short of 3 milliampères. If an experimenter, therefore, states that by such an apparatus he has passed 3 ampères (3000 milliampères) through a man's body, may I, assuming that his spark-gap was not less than one centimetre, representing 9000 volts, conclude that he considers that he has passed through the living body a total energy of 27,000 watts, or 36 electrical horse-power? The second point which this experiment shows me is that painlessness must depend largely on the concentration of current (density). It is absent when spread over the area of a half-crown, and present when concentrated through a three-penny piece; mere rapidity of alternation will not, therefore, *per se*, make a current painless. Rapidity will transform and minimize current-strength (ampèrage), but when such current-strength is concentrated through a sufficiently small electrode (represented in an extreme form by a spark) it becomes painful. Apart, however, from the physics of the current itself, there is that of the conductor—*i.e.*, the body—also to consider; firstly, that ever-varying quantity, resistance, mainly determined, as is known by the condition of the skin, and changing as the skin happens to be dry or damp. The above considerations, looked at collectively, seem to me to point to the probability (1) that currents of high frequency and potential owe their 'harmlessness' mainly to their small current-strength, but that the resistance of the body, certainly, and the independent conductivity of its surface fluid,

possibly, as well as other conditions, may play an important part in explaining the occasional harmlessness of currents of ordinary frequency and admittedly large current-strength; (2) that sensation and muscular contraction are influenced by the frequency of the alternation, the extent of changes of potential, and the suddenness (brusqueness) with which the change is made,—*i.e.*, by the shape of the electrical curve, of which these three are factors,—three factors whose effective action is determined also by the degree of current-strength and its concentration on a given area."

The following letter, which was sent to each associate editor, and accompanying key and blank for associate editor's reply, show the plan adopted for securing the opinions of all on medical electrical appliances, thus guaranteeing complete freedom from the charge of favoritism:—

1716 Chestnut Street,
Philadelphia, Pa., U. S. A., March 28, 1892.

My Dear Doctor:—

In order to arrive at a just appreciation of the value of the various appliances now upon the market for the use of the physician interested in electro-therapeutics, and also that the "International System of Electro-Therapeutics" may present to its readers the novel and invaluable feature of a tabulated list of preferences from those who are most competent to speak upon the subject, I have sent to each associate editor this letter, with tabulated form to be filled out, one sheet to be detached after filling out and to be returned to me at your very earliest convenience, and this letter to be retained by the associate editor for future reference. You will please use the numbers as they appear in the Key (on the back of this sheet) to designate your preference, giving your first, second, and third choice, instead of giving the name of cell or battery, which would consume much space In your remarks, explanatory of why you prefer certain instruments, you will limit yourself to one hundred words in each instance. If each associate editor will do me the honor to fill out this blank, I shall be able to issue a most complete and unique classification; this, too, will be of service to the manufacturer, who may realize what changes should be made in his wares to meet professional wants. You will understand, also, what a protection this will be to me, the editor, in guarding against any possible charge of favoritism.

In the "Remarks," gentlemen may specify what features of certain machines are commendable, although the same machine may not be their first preference.

Faithfully yours,

Horatio R. Bigelow, Editor.

P. S.: If, by any inadvertence or oversight, any useful make of static machine, coil, cell, or cabinet battery, etc., of which you have knowledge, has been omitted in my enumeration in the accompanying list, please indicate same as your first, second, or third preference in the column for remarks. H. R. B.

NAME.	PREFERENCE.	STATIC MACHINE.	COIL.	CELL.	CABINET BATTERY.	PORTABLE BATTERY.	CAUTERY BATTERY.	CONTROLLER.	METER.	REMARKS.
Wm. H. Walling.	First. Second.	1 2	7 4	2 1		3 11	4	1	7 5	If No. 2 was a self-charging machine it would be preferable. With the largest and best coil of the No. 7 we get combinations by means of switches, not allowable in any other coil. It is hard to choose between these cells. The Axo has large internal resistance, but is otherwise good. Do not like any of the cabinets sufficiently well to express a choice. The so-called dry cell, when properly constructed, will furnish the ideal portable battery. Cautery battery, No. 4, constant and reliable. Thus far, among those I have used, I consider the so-called Massey Controller the best. No. 5 is preferable from its position, *i.e.*, upright. No. 7 is an accurate and most excellent instrument and is portable.
I. S. Knox.	First. Second. Third.	1 4 6	2 1 4	Diamond Car. 1 8	7 2 5	7 8 5	2 4 5	2 Bailey.	2 1	
F. H. Martin.	First. Second. Third.	1 6	2 1	Diamond Car. 4 1	Diamond Car. 1 7	7 5 2	2 4 5	2 1	1 8 4	
P. S. Hayes.	First. Second. Third.	1 2	Caldwell & Gillett, made by H. C. Sample, Chicago. 2	Sampson, a form of Leclanché. 2 10	7, as modified by myself. 8	7 2 6	3 1 4	2 1	8 1 4	I prefer No. 1, because of its simplicity of construction and freedom from leakage of the static electricity. My preference for the C. & G. coil is because the helices are so wound that the primary will saturate the secondary coil, and the rheotome for rapid interruptions is easily controlled and gives a very even current. The Sampson cell is practically indestructible, and is of large ampèrage for a Leclanché cell. I believe, for therapeutic purposes, the galvanic current should be increased or diminished one cell at a time; hence, my preference for a cabinet battery with a switch, rather than one with a rheostat, for the increment or decrement of the current. No. 7 portable battery, for its compactness, ease with which injured and corroded parts can be replaced, and the facility with which it can be recharged. No. 4 cautery is to be preferred only when the physician has a suitable commercial current for charging in his office. I have yet failed to find anything in the form of a controller that began to meet my ideal. No. 8 meter, on account of the small resistance of the coils and the ease with which disturbing and modifying causes can be detected and overcome.
W. Mills.	First. Second.		Du Bois-Reymond's Inductorium.	5 1		The Cambridge (Eng). Inst. Manf. Co.				Those indicated seem to serve best for the purposes of the physiological laboratory.
John Byrne.	First.						The Byrne Battery.			Manufactured by Kersten & Kaysen, Surgical Instrument Makers, Joralemon St., Brooklyn.
E. H. Grandin.	First. Second.	2	1	1	3	3 4		Gunning's. 3	1 4	Gunning's controller is not used in the key, but, after an extended experiment, I prefer it to any other.

NAME.	PREFERENCE.	STATIC MACHINE.	COIL.	CELL.	CABINET BATTERY.	PORTABLE BATTERY.	CAUTERY BATTERY.	CONTROLLER.	METER.	REMARKS.
A. W. Alleman.	First. Second.	2	Not satisfied which is best.	1 11	3	6 7	Metcalfe.	5 Graphite & Cotton.	5 6	The Metcalfe Storage Cell, manufactured in Brooklyn, I have found most satisfactory. In most instances, I have not been familiar with enough satisfactory instruments to have a second or third choice. The rheostat that I prefer is one made by the Barrett Co., which they did not put on the market.
H. R. Bigelow.	First. Second. Third.	1 4 3	4 2 3	1 2 8	2 7 1	6 7 2	1	1	1 2 3	The Vetter Portable Battery, which I have only recently seen, is a most admirable one. Perhaps the best. The Vetter Meter is also up to the Weston standard, and, therefore, equal to Gaiffe. Dr. Morton's new static machine has a brilliant future.
G. J. Engelmann.	First. Second. Third.	2 6	1 4 2	1 2	3 2	1 3 6	2 1	4 1	1 4	Coils without decidedly variable interrupter and a series of secondary coils are useless for gynæcological or any delicate work. I believe the new form of Leclanché best, although there is hardly a choice between the numerous muriate of ammonia. Lime-carbon cells best without porous cup. I must have rheostat and switch-board; if only one, switch-board preferable. Dry cell preferable, if in city where readily replenished. That which is, perhaps, in truth, the best as a scientific instrument, is not suited in price or convenience to the wants of the practitioner. It is not fair to place instruments 1, 2, 3. Very little choice; any one but "water" is good; smaller ones preferable, as taking less space. I prefer Gaiffe as an all-around meter for the practitioner; certainly for gynæcological purposes. For the neurologist, in this country, I prefer Waite & Bartlett. Preference is given not necessarily to what is absolutely best, but to the instrument best adapted to the American practitioner for his actual work.
A. H. Goelet.	First. Second. Third.	2 4 Gautier's.	Goelet's, made by the Chloride of Silver Dry Cell Battery Co. Baltimore, Md. 4 1, and Law, made after my suggestion.	1 2 6	3 4 1	8 3	Dr. Byrne's.	1 Goelet's Slate Pocket Controller. Willm's.	4 W. & B.'s No. 3. 1 Vetter's.	Gautier has a perfected static machine which, I understand, is superior in many respects. I do not recommend any coils for gynæcological work unless made according to my suggestions in the paper read before last meeting of the American Electro-Therapeutic Association. The Chloride-of-Silver Dry-Cell Battery Co. make an excellent portable two-coil faradic under my instruction. All cabinets should have resistance coils or an ohm-meter attached. I would not recommend any portable galvanic battery which is made without a rheostat for regulating the current. Goelet's controller is made by the W. & B. Co. I prefer W. & B.'s No. 3 meter. The meter of J. C. Vetter & Co., N. Y., should be mentioned with favor.

NAME.	PREFERENCE.	STATIC MACHINE.	COIL.	CELL.	CABINET BATTERY.	PORTABLE BATTERY.	CAUTERY BATTERY.	CONTROLLER.	METER.	REMARKS.
Morton Prince.	First. Second. Third.	4 2 1	3	11 2 1	6 1	6	4	Bailey. 1	Edelman. 8 6	With many of the apparatus here classified I have no practical familiarity, and I am limited by this fact in statement of my choice. Preference for a cell must depend upon the purpose for which it is used. A different kind of cell is needed for neurological, gynæcological, and cautery purposes. The preference here given refers to neurological work only. The Bailey, not mentioned, peerless as "water" controller, is best for neurological work. The Edelman, not down on the list, is superior to all other meters.
C. E. Riggs.	First. Second. Third.	Berge. 2	1 5	Axo 2 11	3 1	6 3	1 3	Law. 1	1 4	I was surprised to see the Berge "static" omitted. Have used it constantly for the last nine years and have found it most satisfactory. I regard the Waite & Bartlett as a most excellent instrument. I use a wall cabinet (Axo, 70 cells) made by Waite & Bartlett, which I prefer to the regular cabinet.
W. F. Robinson.	First. Second. Third.	2	1 2 7	2 1 11	3 7 2	6 7 3	4 2 1	3 4 1	2 4 5	As far as my knowledge goes I consider the Holtz machine, made by Waite & Bartlett, to be the only suitable machine for medical purposes. I prefer the Law Cell because I believe it to be as durable as any other, and, in addition, it is little or no trouble to renew. All batteries which have porous cups are unsatisfactory to renew when once used up, on account of the difficulty of depolarization. The only cell which gives any comfort at all for cautery work is a storage cell. Primary cells rarely, if ever, give power enough. The best water rheostat is what is known as the "New Bailey," only lately put upon the market. The ordinary "Bailey" instrument was defective because the current could not be started gradually.
L. Smith.	First. Second. Third.	2 1 6	4 1 5	2 1 8	3 1 8	8 6 3	4 1 2	Bailey. 1 4	1 1 1	I have found Gaiffe's the most reliable of all. As it has not quite a long-enough fine-wire coil, I have had one made by the Bell Telephone Co., Montreal, with a fine-wire coil 1500 yards long, and an interchangeable interrupter, and a ratchet to advance or retreat the secondary coil. The secondary coil is tapped at 500, 1000, and 1500 yards. It is only half the size of Gaiffe's. Waite & Bartlett's cabinet also contains a storage battery and a gravity battery for charging the same, enabling one to do cautery work at a moment's notice. Portable battery has the advantage of being both portable for outside work and yet powerful enough to do for office work and to last without recharging for several months. I have found no other galvanometer to be compared with Gaiffe's.
F. Peterson.	First. Second. Third.	7 2 6	8 5 4	1 11 2	3 5 1	6 8 3	1 4 3	1 3 4	Hirschmann's 6 4	Hirschmann's absolute galvanometer is the best by far (Berlin).

NAME.	PREFERENCE.	STATIC MACHINE.	COIL.	CELL.	CABINET BATTERY.	PORTABLE BATTERY.	CAUTERY BATTERY.	CONTROLLER.	METER.	REMARKS.
G. B. Massey.	First.	5	3	1	2	2	1	1	5	Flemming's is preferred only when accompanied by a coarse-wire secondary coil. The slow interrupter is of value in neurology. Nos. 1 and 2 cells for stationary purposes and the acid (Grene's) for portable. The chief advantages of this cabinet are simplicity, convenience, and its beautiful finish. Acid portable batteries only have been satisfactory. The chief advantages of my controller, in its most recent pattern, are ease of manipulation (particularly in administering swelling currents), portability, durability, and the fact that the resistance can be reduced to zero.
	Second.		1	2		3	4		2	
	Third.		5	6		7				
W. J. Morton.	First.	2	1	1	3		1	1	2	Neither of the coils mentioned, so far as I am aware, is worthy of medical attention. The Edison has a fine and smooth vibration, and gives a smooth and not too painful current. The Gaiffe may be excellent; I know nothing about it. There can be no good "coil," in a medical sense, which does not permit of substituting different secondaries according to the physician's requirements. We need a standard coil. This means, of course, that every part of the coil, battery, primary core, secondary vibrator, and scale must be standardized. In expressing my choice, I do not mean to draw invidious distinctions, for many among those mentioned are unfamiliar to me; some mentioned, I think, should be purposely left out. Many makers are good in some one thing, and indifferent or bad in others.
	Second.	4	8	8	Edison.		4		4	
	Third.						5		3	
H. McClure.	First.	3	4	1						Lereu has the merit of being, to a great extent, uninfluenced by temperature, moisture, or dust, as the generating part is inclosed.
	Second.	4	2	9						
	Third.	7								
R. Newman.	First.	2	1	4	3	4, H. E. Stammers, 1426 Br'dway, N. Y.	4, Waite & Bartlett.	Utrecht, Holland.	3	H. E. Stammers, 1426 Broadway, N. Y., does very satisfactory work; his battery is just as portable as an acid battery can be portable. The low price is inviting the patronage of the general practitioner. Storage batteries are best for the office, and if daily used. As a portable cautery the Dawson, made by Geo. F. Tiemann & Co., N. Y., excels on account of its small size, its strength and durability. Elements: carbon and platinum. The Utrecht rheostat I consider best. Waite & Bartlett's instrument is a good imitation of the same. The new meter of Waite & Bartlett does not need to be carefully balanced; hand is firm, not hanging on a frail fibre, and the meter marks more correctly.
	Second.		7	1	2	3	Metcalf.	4	4	
	Third.		3	5	4	2	Dawson's.	1		
E. L. H. McGinnis.	First.		4	7	8	8	Have not used.	4	1	
	Second.		1	11	3	3		3	4	
	Third.					6			6	

KEY.

STATIC MACHINE.	COIL.	CELL.	CABINET BATTERY.
1. McIntosh. 2. Waite & Bartlett. 3. Carré. 4. Wimshurst. 5. Queen. 6. Gaiffe. 7. Lewandowski.	1. Engelmann (W. & B.). 2. Tripier Induction (McI.). 3. Duchenne (Flemming). 4. Gaiffe. 5. Law. 6. Galvano-Faradic Co. 7. Kidder. 8. Edison.	1. Leclanché. 2. Law. 3. Crosby. 4. Bunsen. 5. Daniell. 6. Grenet. 7. Gaiffe. 8. Lalande. 9. Smee. 10. Gravity. 11. Chloride of Silver Dry Cell.	1. Law. 2. Flemming. 3. Waite & Bartlett. 4. Kidder. 5. Galvano-Faradic Co. 6. Chloride of Silver Dry Cell Battery Co. 7. McIntosh. 8. Gaiffe.

PORTABLE BATTERY.	CAUTERY BATTERY.	CONTROLLER.	METER.
1. Law. 2. Flemming. 3. Waite & Bartlett. 4. Kidder. 5. Galvano-Faradic Co. 6. Chloride of Silver Dry Cell Battery Co. 7. McIntosh. 8. Gaiffe.	1. Edison. 2. McIntosh. 3. Piffard. 4. Storage. 5. Dynamo.	1. Massey. 2. McIntosh. 3. Water. 4. Waite & Bartlett. 5. Chloride of Silver Dry Cell Battery Co. 6. Gaiffe. 7. Kidder.	1. Gaiffe. 2. Weston. 3. Hutchinson. 4. Waite & Bartlett. 5. Flemming. 6. Chloride of Silver Dry Cell Battery Co. 7. Kidder. 8. McIntosh. 9. Galvano-Faradic Co. 10. Queen.

"On Wednesday, the 3d of February, the Royal Institution was crowded with one of the most critical scientific audiences in the world, who were held spell-bound for more than two hours while Mr. Tesla gave an account of his discoveries. Mr. Tesla is a young electrician born at Rieka, on the border of Montenegro, and now domiciled in America. The interest of the lecture lay not in the beautiful experiments with which it was illustrated, nor in the actual facts put forward, but in the hope held out that we may now draw back a little farther the veil which hides one of the most fascinating mysteries of nature, namely, the relations between light and electricity, and between matter and motion.

"The tendency of modern science is to remove, day by day, the barrier between its different branches. Our views of the phenomena of light and heat, of electricity and magnetism, and even of matter and motion, are rapidly merging into one general theory of molecular physics, which is, perhaps, best expressed by the vortex theory of Sir William Thomson.

"According to this theory the whole of every part of space is filled with a fluid called ether, almost infinitely thin, and almost infinitely elastic. The historic experiment of Faraday, interpreted by the mathematical researches of Clerk Maxwell, have demonstrated, almost beyond doubt, that the same ether whose waves carry light and heat from the sun and stars to the earth also carries the waves of the electric and magnetic induction, which, as daily experimented at Kew Observatory shows, follows each outburst of solar activity.

"Sir William Thomson holds that all that which we hold as matter consists of vortices or whirlpools of this ether, which, from their rapid rotating motion, resist displacement, and therefore show the common properties of hardness and strength in the same way as a spinning top or gyroscope tends to keep its axis in a fixed direction. But whether the molecules or particles of what we know as matter are independent matter, or whether they are ether whirlpools, we know that they keep up an incessant hammering one on another, and thus on everything in space.

"Professor Crookes has shown that the forces contained in this bombardment are immensely greater than any other force we have yet handled, many millions of horse-power being contained in an ordinary room. Owing, however, to the forces being in every possible direction they neutralize each other, and no result of them is perceivable to our senses; but if ever we discover how to direct their course as to send the majority of them in the same direction, we shall have at our disposal forces as much exceeding any we are now acquainted with as the blow struck by a bullet exceeds the force required to pull the trigger of a gun. In fact, as Mr. Tesla puts it in his lecture, 'We shall then hook our machinery on to the machinery of nature.' It is because they hold out to us a hope, however distant, of some day so guiding the ether

storm, that the experiments of Nikola Tesla are of such transcendent interest and importance.

"Professor Crookes, in his experiments on 'radiant matter,' has given us the first hint of a method of directing what, for want of more-exact knowledge, we will call the molecules of matter. With the appliances at his command, however, he was unable to impart any great change of direction, but he succeeded in making that change manifest by reducing the disturbing forces against his directing force. In other words, he pumped out from glass bulbs and tubes nearly all the air or other gas they contained, and the comparatively few particles left were then free to travel in any course imparted to them without much change caused to them by collision with others. This special direction was imparted by means of electricity, and gave us the beautiful phenomena of phosphorescence and the radiant matter which are now so well known in these experiments.

"By means of suitably-shaped terminals a stream of molecules is focussed on a given point. If a piece of carbon or platinum is placed at that point it becomes white hot under the bombardment, from identically the same cause which causes a sheet of flame to appear when a cannon-shot strikes an iron target. If a ruby or other phosphorescent material is placed, there is a glow with its characteristic color; and if a little delicately-balanced vane or windmill is placed so that the stream is directed on one side of its fans, it rapidly revolves. The forces available in these experiments were, however, almost indefinitely small, being, as it were, merely flying sprays from the great torrent into which we had not been able to penetrate.

"We now come to the advances made by Mr. Tesla.

"In all the above experiments the electricity by which the directing force was imparted to the molecules was electricity of a comparatively slow alternation period, namely, electric currents oscillating about eighty to one hundred times per second. It was as if he had tried to ventilate a room by causing a man to walk slowly through it with an umbrella. He would undoubtedly move the air, but would move it so slowly that ordinary methods would be insufficient to enable us to perceive its motion. In order to cause a rush of air we must put up a rapidly-moving fan or other suitable machinery. Mr. Tesla, seeing this, abandoned the ordinary dynamo, which, as we have already noted, gives about eighty alternations per second, and the ordinary induction coil, which gives about the same number, and boldly constructed a dynamo which gives twenty thousand alternations per second, and by connecting this to suitable condensers he multiplied its alternations until it reached one million, or one million five hundred thousand per second.

"Then at once an entire new set of phenomena appeared, and the experimenter entered a region of mystery and hope. One of the first things noticed was that, either because these vibrations are too rapid to

excite corresponding vibrations in the nerves of the body or for some other cause, no shock is felt from the current; and that, though an ordinary current of 2000 volts will kill, yet this current at 50,000 volts cannot be felt at all.

"It was also found that the vibrations keep time, in some unknown way, with the vibrations of solid matter. Vulcanite is one of the best insulators known, and will entirely stop any ordinary current or discharge, but the stream of sparks between two poles with this current pours through a thick sheet of vulcanite as easily, or even with greater ease, than through the air. It does not perforate it in any way, but passes through it as light passes through glass.

"All the Crookes phenomena of radiant matter are almost infinitely increased; it is the blow of mitrailleuse-bullets compared to the blow of an iron ball thrown against the wind. The forces can be directed for a considerable distance through space without the aid of wires. Electric lamps light easily when attached to one single wire, and require no return conductor; and, more wonderful still, if metal plates are fixed on the walls and roof of a room, and connected to the terminals, the whole atmosphere of that room, whether it be ether or whether it be particles of common matter, is thrown into a state of storm and agitation, which can be at once made perceptible by bringing into the space tubes or globes from which the air has been partially exhausted. Such tubes, though without any metallic connections, yet glow and throb as if powerful currents of electricity were being sent through them from an ordinary induction coil.

"A Crookes radiometer placed near a metal conductor, from which neither spark nor glow is perceptible, yet rotates as if it were placed near a lamp or heated body, but rotates in the wrong direction, and, last of all, a true flame burns in which nothing is consumed.

"When the discharge issues from a suitable terminal it has the appearance and roaring sound of a gas-flame burning under too high a pressure, and gives off a considerable heat; to use Mr. Tesla's words again: 'This is not unexpected, as all the force and heat in the universe is due to the falling together of lifted weights, and the same result is produced whether these weights have been lifted apart by chemical energy, and rest in the form of oxygen and hydrogen ready to combine chemically, or in the form of mechanical energy of moving molecules directed by the electric current.'

"On the same table on which Mr. Tesla's experiments were shown, a few days ago, there swung, in the year 1834, a delicately-balanced galvanometer needle, under the influence of the first induction current, produced by the genius of Faraday. The force available to move it was very small, probably not greater than the forces lighting Mr. Tesla's tubes, yet that force has now developed one of the greatest industries of the world. It lights millions of lamps in London and elsewhere; in

America it drives cars on thousands of miles of railways, and will soon distribute the power of Niagara Falls to the inhabitants of the neighboring States. May we not hope for some such developments of the new discovery, and that we shall some day harness to our machinery the natural forces which, from the beginning of time, have literally been slipping through our fingers ?"

The animadversions that have been heaped upon electrotherapy by incompetent people are merely the echoes of that past ignorant conservatism that bewailed the advent of the steam-railway and of electric house-lighting. The whole process of life is merely a force manifestation in which electricity has its place. Disease is a difference of potential somewhere; to establish a just equilibrium we must correct the abnormal electric conditions.

The editor cannot allow the occasion of his indebtedness for many courtesies to pass by unnoticed. The publishers have been more than kind to him, and Mr. George B. Johnson, who has had immediate charge of the detail work, has been constant in season and out of season. Mr. H. B. Van Horn is a prince among printers. Whatever of merit is found in the typography and setting is due to him. His patience under trying circumstances has been marvelous, and to his wisdom in his chosen art is due the present good appearance of the book.

The editor's associates have been generous in their co-operation and forbearing in their impatience at many delays.

Each paper is a classic of itself. The index is prepared by Dr. Witherstine, which makes extended comment unnecessary.

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INTRODUCTION.

THE NECESSITY FOR SPECIAL EDUCATION IN ELECTRO-THERAPEUTICS.

By WILLIAM J. HERDMAN, Ph.B., M.D.,

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About ten thousand physicians within the borders of the United States make use of electricity as a therapeutical agent daily. Many others find occasional use for it. The surgeon and the ophthalmologist, the dentist and the gynæcologist,—in fact, the specialist in whatever field,—finds it a valuable aid to treatment, an indispensable handmaid. It is the mainstay of the neurologist both in diagnosis and treatment, and the rapid increase of exact knowledge in this branch of medical science is largely due to the service it has rendered. The more familiar we become with the manifestations of electric energy, the more do we recognize its adaptations to the requirements of disordered physiological conditions. It is this lack of familiarity, on the part of the members of the medical profession, with the laws of electro-physics and physiology, more than any other cause, that has retarded the progress of electro-therapeutics. Had every student during the past decade been made acquainted, during his medical course, with the action of electric energy upon the various tissues of the human body, and had he been instructed in the management of such appliances as are commonly employed for controlling such energy, there is not a general practitioner or a specialist among them who would not be making daily use of it in his practice with increased satisfaction to himself and benefit to his patients.

So wide is the range of adaptability of electricity to the treatment of disease that it must become the common property of every physician, no matter whether his work is general or special in its nature, and, such being the case, instruction in electro-therapeutics should have a place in every medical-college curriculum. It is not generally understood what such instruction requires to be of any value to the student.

It is useless for an instructor to attempt the inculcation of therapeutic rules in the use of electricity to a class not familiar with the physical differences between frictional, voltaic, and induced currents; and it is worse than useless for the members of that class to attempt the application of such instruction to the patient if they are unfamiliar with the management of the machinery by which such different forms of electric energy are applied. Such attempts are but doomed to ignominious

failure, discouraging the physician and disgusting the patient, while the abused agent bears the blame until better methods prevail.

To-day the practicing physician needs not to be a pharmacist in order that he may skillfully administer his remedies, for the intermediate work of preparation of medicines for his use is now most ably done, and such knowledge, while it might serve a good purpose in enabling him to detect substitutes and adulterations, would, for most practical purposes, consume time that might be spent to better advantage. With reliable strength and purity, his drug is furnished him in abundance ready at hand; its dosage is simple, its physiological action comparatively uniform; he need but to learn the idiosyncrasies of his patient and his course is clear. But when employing electricity as a remedy a wider range of knowledge is demanded. The operator must know in minutest detail how to generate and control it, to measure and modify it, and be possessed of a manual dexterity in locating its action on the part to be influenced by it. Here is a science and an art to be acquired that needs other methods than the didactic lecture and the text-book. He must not only be well versed in the principles that guide the physicist and skilled mechanic who constructs his electrical apparatus, but he must himself be able to suggest wherein that apparatus may be the better adapted to the special needs of his patients. He must not be dependent upon the enterprising but non-professional commercial agent for information as to what form of electricity to use, and how to use it in certain cases.

The merchant has adopted the rôle of instructor to members of the medical profession, and has many eager auditors. The demand for knowledge is urgent. The schools have not supplied it. The man of money finds it to his interest to respond to it as best he can.

It needs no further illustration or argument to show that the time is ripe for systematic instruction in electro-therapeutics in our medical schools. The profession at work in the field recognizes its needs. The extensive list of disorders yielding to such treatment renders it indispensable. Some medical colleges have for some time recognized its importance and necessity, and have provided for it. Others are falling into line, and soon all will be teaching electro-therapeutics in some manner. But how should it be taught in order that the best results may be attained, and the science most rapidly advanced? What ought the physician to know who undertakes the therapeutical application of electric energy if he would direct his treatment with an intelligent purpose and most efficiently?

First of all, he should be well drilled in the physics of electricity and magnetism. By common consent among educators, such knowledge can be best acquired by laboratory drill, where sight and touch are added to hearing as channels for mental impress, and where the attention is aroused and fixed with greater certainty and success. The student of electro-therapeutics should begin with practical laboratory experience in

the management of continuous-current generators, primary batteries, secondary batteries, dynamos and induction coils, and other apparatus for creating electric energy and for conducting and applying it to the body. It is just as essential for the would-be electro-therapeutist to be brought face to face with, and to learn to overcome, the obstacles that tend to prevent an equable and constant flow of electric energy from a primary battery, as it is for the would-be surgeon to familiarize himself with topographical anatomy in the dissecting-room. Such knowledge is fundamental. There is no time for the one to consult an electrician any more than for the other to refer to a text-book while a treatment or operation is in progress, and an emergency calling for prompt action is as likely to arise with the one as with the other. Physics is not among the requirements for entrance to many of our medical schools, and even those who have had instruction in physics such as is ordinarily given in high-schools and academies do not without a laboratory-training acquire that manual dexterity which is indispensable for managing electric apparatus successfully. Moreover, the laboratory instruction which the electro-therapeutist requires needs to be arranged with special reference to the problems he is to encounter. The resistances with which he has to deal are those of the human body; the electrolysis, that of living tissue; the range of voltage, such as can be borne without harm to vital structure. There are implements and conditions peculiar to the work with which he must become practically acquainted. A laboratory course designed to meet these requirements, and properly educate the medical student to practice electro-therapeutics, naturally divides itself into three divisions, by reason of the character of work pursued in each, and the dependence of each upon that which precedes it. These divisions are: I. Physical; II. Physiological; III. Therapeutical.

I. Physical.—The first or *physical* course should be arranged with a view of presenting to the student all the practical points that are likely to arise in the use of machines for generating static electricity, continuous and interrupted currents, for medical purposes. In order to accomplish this, each student should be required to construct (from the raw material, as far as practicable) his own batteries and other appliances for generating such currents, and for applying them to the body. And where for any reason such appliances are furnished ready-made they should be constructed in the simplest form consistent with efficiency, and their constituent parts left bare for inspection, if possible, so that their action is not obscured and the principle lost sight of through any mystery of mechanism.

The course might begin by testing the strength of currents generated by the action of dilute acids on various dissimilar metals, by which the student will find the position which the various metals occupy in the "contact series," and thus learn to choose those which, for reasons of efficiency and economy, are best adapted for practical use in electro-thera-

peutics. Zinc and carbon being found to meet these conditions, experiments can then be made to illustrate the necessity for amalgamating the zincs, and avoiding polarization in battery action, so as to secure a constant and unvarying current. The form of cell which best meets the conditions of constancy, combined with the highest electro-motive force, may then be determined by tests of a large number of batteries, double and single fluid, and dry. Following these tests the students should, for their further work with continuous currents, be required to construct zinc and carbon bichromate eight- or ten- cell experimental batteries, which should be required to register at least fifteen volts as a test of their accuracy in construction. After determining the electro-motive force and the internal resistance of these experimental batteries, problems for determining strength of currents with unknown resistances should be solved, and then, the current being known from a galvanometer-reading, a series of problems should be given to determine unknown resistances, after which the body-resistances can be tested by introducing some part of the body into the circuit. The student should construct his own electrodes for applying the current to the body. Experiments in divided currents, shunt circuits, and joint resistances should then be undertaken, with a view of illustrating the conditions met with in the action of currents when traversing the various tissues of the body.

The student having thus become practically familiar with the phenomena of electric generation and conduction, and the conditions that attend them, the action of a continuous current in producing electrolysis should then be determined by actual test on a variety of ions, the effects peculiar to the anode and cathode distinguished, and illustrations made of the uses for which such action can be successfully employed in dealing with the diseased condition of the body.

The batteries arranged for generating a current suitable for heating a cautery, and the conditions necessary for successful galvano-cautery work, should be experimentally studied. As a part of this work, each student should be required to make a cautery that will stand the test of a current of eight ampères.

Induction currents should be next considered and the principle of magneto-electric and induction machines inculcated by the construction of temporary magnets, and a study of the phenomena they exhibit in taking on and parting with their magnetism. An induction coil generating primary and secondary induced currents, similar to the ordinary medical induction apparatus, should be put in the hands of each student. It should be so constructed that its mechanism can be readily seen and the courses of the various currents traced. With this apparatus experiments can be conducted upon the body, illustrating the physiological effects of interrupted currents of high electro-motive force on tissue-action.

Frictional electricity should be illustrated by several forms of static

machines, and the student instructed how to operate them for therapeutic applications.

This course of laboratory instruction would consume a period of a longer or shorter time, according to the preparation the students have had in natural science, and as the requirements for entrance to our medical schools advance such practical knowledge of the physics of electricity as is here outlined might with propriety be demanded of the matriculant. No matter where or how acquired, such preparation is indispensable before the student can with any profit undertake the work that pertains to the remaining divisions.

II. Physiological.—Under this head should be arranged a series of laboratory experiments designed to illustrate the manner in which the various living tissues in animals and man respond to the electric stimulus.

No branch of medical science has had more able investigators, or been more fruitful in yielding rich returns, than that of electro-physiology. Such investigations have furnished a firm foundation for electro-therapeutics, and should be made the starting-point for practical instruction. Yet the conditions under which experimental results are obtained in the physiological laboratory differ so materially from those under which the operator in electro-therapeutics is called upon to labor, that a physiological laboratory training is not adequate to supply the needs of education for the electro-therapeutist. In electric experiments in the physiological laboratory, the result has been determined upon a decapitated or narcotized animal with nerve or muscle or viscus brought into immediate contact with the electrodes, while the physician in electric applications deals with the human subject when the cerebral functions of his patient are active and alert, and the skin or other structures intervene between the electrodes and the tissue or organ to be influenced. These changed conditions require methods of investigation peculiar to themselves. A series of demonstrations on the human body intact and in a normal state is the rational prelude to attempts at therapeutical applications.

The student should first be required to obtain the normal nerve and muscle reactions in various parts of the body with both continuous and induced currents, noticing the amount of current required, its density, and the points where the electrodes must be applied to get a prompt response. This range of experiments presupposes thorough anatomical knowledge, and reveals its necessity to the student more convincingly than any verbal argument. These experiments can then be varied by producing overaction in the muscle so as to weary it, and exhibit the retardation in response to stimulus. In an animal the nerve may then be cut, or paralyzed with curare, and the experiments repeated, exhibiting the effects of injury or disease.

The student thus becomes practically familiar with the differences in the polar action of the continuous current in exciting normal reactions in nerve and muscle. The electrolytic action upon living tissue can then

be tested with electrodes of various sizes and material. The effect of density upon the skin from dry electrodes is a most valuable lesson to inculcate, since in unskilled hands the continuous current is capable of doing serious damage to a patient, causing eschars that are extremely slow to heal. The electrolysis of deep-lying structures should be so conducted as to avoid wounds upon the surface from the action of the needles employed. The manner of introducing and insulating them for work of this kind demands experience and skill of a high order. No one will deny that such skill should be attained before the operator attempts it upon a patient, and that superior anatomical knowledge is here also an indispensable requisite for safety in such operations.

Another very common use for the electrolytic action of the galvanic current is the removal of facial blemishes, the technique of which can be very readily acquired in the laboratory.

Cataphoresis, or the introduction of remedies into the tissues through the agency of the anode of a continuous current, affords another field for laboratory demonstration that is destined to prove of great value in therapeutics. The range of remedies that can be thus effectively introduced through the skin and mucous membranes for local or systemic effects are already known to be many, and the laboratory is the proper place for conducting such investigations as will enlarge upon and perfect this method of medication. By employing certain of the lower animals for the purpose, the underlying tissues can be subjected to examination and analysis after such applications, and the result positively determined. Or, if the tests are made upon man, the examination of the urine and other secretions, or the evidences of the known physiological effects of the drug, can be sought for as evidence of the efficiency of the method. It is in this division of the course that the student should be instructed in the generally-approved methods of electric applications, and be made familiar with the physiological effects to be expected from each. Thus, "general faradization," "galvanization of the sympathetic," "local galvanization," or "faradization" of the special-sense organs, and special systems or organs of the body, can be arranged as a series of experiments. The methods and instruments employed to reach internal organs for direct application of currents to them, as the vocal cords, Eustachian tube, the œsophagus, the stomach, the rectum, the bladder, the urethra, the vagina, and uterus, all of which the student should be practiced in before attempting actual therapeutical work, afford a wide field for gathering important information and experience.

The physiological effects of frictional electricity should also form a part of the course of instruction under this head. The cutaneous excitation, the vasomotor change, the increase of circulation, and the so-called "refreshing effects" and the sensations produced by the "electric breeze" can be readily demonstrated, and skill acquired in the management of electrodes for the purpose of producing them.

The student who has been through a practical drill, such as is here outlined, will enter upon the final or therapeutical course with a preparation that will insure him against innumerable blunders, and arm him with a confidence in the agent he is employing that is a guarantee to success.

III. Therapeutics.—The student should now have the opportunity in the hospital wards, the operating-room, and the out-patient department to use the information he has already gained, and learn the value of electricity in counteracting disease.

Here he learns to relieve pain, to promote absorption, to quicken torpid nutritive processes, to excite secretion, to stimulate muscular action, to revive nerve inactivity, to arrest hæmorrhage, to heal ulcerations, to dissipate strictures and tumors, and to cauterize and destroy abnormal growths by means of electricity in one or the other form with which he has become familiar. The therapeutical work goes hand in hand with his study of pathology and diagnosis, and he learns to recognize the diseases most amenable to electric treatment and the method of application best adapted to each. As far as is consistent with the welfare of the patient, the student should be given the entire responsibility in carrying out the treatment when electricity has been found to be an appropriate remedy.

So wide is the range of disorders now found to be helped by electricity that the technique of its management in the clinic has of itself become a matter of so much importance, in many of our hospitals, that a special instructor is appointed to take charge of it. Under his direction the student can be well drilled in all the details of its application in a variety of diseases. The methods employed and the machinery made use of in many of our dispensaries and hospital clinics giving electric treatment are admirable, and the results all that could be desired, but the instruction is oftentimes of little practical value to the student when he begins his own private work, because of his inability to duplicate or maintain the expensive outfit with which he has been accustomed to work, or because any additional information which he may seek to obtain from other sources is couched in language which he does not clearly comprehend by reason of the difference in terms and methods of treatment adopted by those who practice electro-therapeutics. A disparity of results arises also between those who employ electricity in practice, because of a lack of uniformity in the apparatus employed. The rapid advances which all who are personally familiar with the capacities of electricity in one or other form as a curative agent know it to be capable of making are greatly retarded by this lack of uniformity in method and machinery. Electro-therapeutic apparatus can be reduced to much greater simplicity and still retain all the efficiency that it has been shown to possess. Primary- and secondary- current batteries, medical induction coils, milliampère-meters, rheostats, and dynamo-current controllers for medical uses should be made in accordance with standards adopted or approved by the com-

mon consent of those who have proved by their work the value of such patterns. When it is possible to report the treatment by electricity of a well-known pathological state in terms of exact dosage by standard instruments,—all of which is within the range of possibility,—then electrotherapeutics will have reached a stage when its claim to be recognized as an exact science will be far in advance of many other branches of medicine, and the art will keep pace with the progress of the science.

ELECTRO-PHYSICS.

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1. Purpose and Plan of this Section.—There are always two ways in which a scientific instrument can be used,—the blindly mechanical and the intelligent. In the former the employer of the instrument follows certain rules laid down for its use by the inventor, or some one who knows more of its nature and construction. In the latter the employer is constantly verifying and modifying the rules of thumb supplied with the instrument in accordance with what he has learned of its inner mechanism and principle of action; that which Clerk Maxwell, in his childish questionings, called the "go" of the thing.

Now, this first section is intended chiefly for the intelligent medical man who, just as he desires to know the chemical constitution of the drugs he prescribes, desires also to know all that can be acquired without undue labor of that agent—electricity—that has come to be one of his most important tools. Specialists in medical subjects will treat of the different sections under which electrical phenomena have been grouped (voltaic, faradic, franklinic), and will do so from the point of view of their medical applications; and it is considered that a connected view of the whole subject, showing the relations of those great parts and sketching in the intervening districts, will serve the reader as a preliminary view of a strange city from a high eminence serves the intelligent traveler before he descends to plunge into the labyrinth of streets. While an attempt will be made to treat all the fundamental principles of the subject in a simple and easily intelligible way, yet those parts which are most pertinent to medical applications will be treated more fully than less pertinent parts. Especial care will be taken to define and explain technical terms, while less attention will be given to the details of experimental methods and apparatus.

To save frequent digressions in the treatment of electricity itself a concise statement of some parts of general physics is prefixed, and will be referred to, as occasion arises, at different points.

2. Process of Physical Advance.—When attempting at the end of this section to explain what electricity is, what shall we mean by such an explanation? What we mean is, that we shall bring it into line with other more familiar, though perhaps equally unexplained, facts. This is the process of physical explanation,—the reduction of two problems to one. Thus, we shall attempt to show that ordinary mechanical principles and the medium called the ether postulated by light suffice to explain electricity.

3. Matter and Energy the Only Real Things in the Physical Universe.—In discussing what electricity really is, we shall be confronted by the question, What is the test by which we distinguish between things existing in and by themselves and mere relations between things, or between things and us,—that is, ways in which we view things? The former are objectively existent things, the latter merely appearances, and they stand to each other as a landscape to a mirage. Now, the test we adopt is this: A thing does not change in total quantity,—there is no likelihood of the landscape disappearing utterly, whereas the mirage may vanish into nothing; in other words, one is conserved, the other is not. Thus, we take as our test *conservation*, *i.e.*, the property of always remaining the same in quantity.

If, now, with the touch-stone of conservation we try things around us, we shall find that there are but two real things, viz., matter and energy; for each of these is conserved or never varies in quantity. Even force is not a thing, for with a Bramah press or a lever we can, by the exertion of the smallest force, produce the greatest force desirable, and then make it vanish as rapidly. But while matter and energy agree in being conserved, we shall find them differing in a marked way. Each appears in a variety of forms: matter as oxygen, hydrogen, carbon, etc.; energy as mechanical energy, heat, light, sound, and electrical energy. The difference is, that whereas no one form of matter ever (so far as we know) changes to any other form, on the other hand, any one form of energy can change to any other form, its quantity still remaining the same. Hence we say matter is untransformable, while energy is highly transformable. Energy, in fact, only manifests itself in the process of transformation. Its transformability is the life of the physical world, matter its body.

4. Combinations of Different Forms of Matter—Terminology.—At the present time about seventy different forms of matter or *chemical elements* are known, no one of which can, so far as we know, be transformed into any other. But they are capable of uniting two, three, four, etc., at a time, to form compounds differing markedly in properties from the elements. Hydrogen and oxygen are ordinarily gases, but by uniting they form a liquid,—water. This tendency to unite is called *chemical affinity*, and a side-result of electrical advance has been to give a highly probable explanation of this affinity.

Many things indicate that any quantity of one form of matter really consists of very small particles, which, so far as we know, are indivisible, and are hence called *atoms*. All the atoms of any one form of matter are absolutely alike, and chemical compounds are formed by the union of unlike atoms. Hence the smallest part of a compound is really a group of unlike atoms, and this smallest particle is called a *molecule*.

In the union of atoms to form molecules a remarkable diversity shows itself, and will be referred to later. Such unions are not always

monogamous; many are bigamous, trigamous, etc. Oxygen is a highly active bigamist; so that when an oxygen atom unites with monogamous hydrogen atoms to form water it requires two, which is indicated by representing the compound molecule by H_2O. Again, a nitrogen atom takes three monogamous atoms, and so on. This combining capacity of an element is called its valency, and atoms are spoken of as univalent, divalent, trivalent, and tetravalent, or are called monads, dyads, triads, and tetrads.

If, now, we chemically separate such a compound as H_2O into its constituents, the H atoms unite two at a time, to form H molecules, and the O atoms two at a time to form O molecules. But just at the moment of rupture, before this recombination, the atoms are open to accept other partners than ones of their own kind, and hence are at that time in a specially active state as regards readiness to act on foreign bodies. For an obvious reason this is called the *nascent state.*

5. Physical Constitution of Matter—Kinetic Theory.—No very accurate determination of the sizes of molecules is possible yet, but a very rough approximation has been arrived at by Sir Wm. Thomson (now Lord Kelvin) from four different points of view. It turns out that in ordinary liquids and solids there are somewhere between five million and ten billion molecules per inch of length,—that is to say, the centres of two adjacent molecules are separated by something between one-five-millionth and one-ten-billionth of an inch. In a gas the number altogether depends on the density of the gas, and can be reduced to any desired extent by reducing the density of the gas by means of an air-pump. What the actual size of the molecules are, compared with the distance between their centres, we do not know, but certainly it can only be an exceedingly small fraction of that distance.

The progress of research has afforded conclusive evidence that these ultimate particles are not at rest, but are continually in most vigorous motion, however rigid the mass of the substance may be. This motion is of several different kinds:—

(*a*) *Translation of molecules,*—that is, motions by which the molecules move from place to place without any tendency to return. The velocity of this translation may vary widely, and bodies are classified with reference to it into:—

1. *Gases.*—Here the particles continue moving in straight lines until they collide with other particles or with the sides of the containing vessel, when they rebound in new directions. Thus the particles act as quite separate individuals. The velocity of translation in a gas is, on the average, about one-half greater than that of sound in the gas; in the air it would amount, under ordinary conditions, to about 1630 feet per second. This velocity accounts for the great readiness with which two masses of different gases mix when the containing vessels are brought mouth to mouth. The frequency of collision between particles can also be calculated by indirect methods, and also the mean free path, or average distance traveled by a particle between two successive collisions. In the case of hydrogen at atmospheric pressure, the collisions take place at about the rate of 17000 per millionth of a second, and the mean free path is, roughly, four-millionths of an inch. But a gas can be rarefied until the mean free path amounts to several inches.

2. *Liquids.*—Here the particles still have motions of translation, but they are exceed-

ingly small compared with the preceding. Their existence, however, is shown by putting a layer of colorless solution (or water) on a solution of a colored salt (*e.g.*, copper sulphate) and noticing that the two gradually mix by diffusion, as it is called.

3. *Solids.*—Here the velocity of translation is *nil*,—not that the particles are at rest, but they never get far away from their mean positions.

(*b*) *Vibration of Molecules.*—By this we mean a rapid to-and-fro motion in some way or other, such as not to carry a particle far away from its mean position, but to keep it continually moving to and fro around or through it.

(*c*) *Rotation of Molecules.*—By the indirect impact of molecule on molecule, or by some other means, the particles are set into to-and-fro rotations, or it may be continuous rotations.

(*d*) *Oscillation of Atoms in Molecules.*—Finally, the atoms in a molecule are in violent oscillation in a number of ways; and by different means (*e.g.*, heat) these oscillations may be increased in violence until the atoms part company and the molecule is dissociated. The rapidity of these motions can be readily determined from the color of light to which they give rise. It is very great. For instance, an atom of sodium oscillates in three different ways,—at the rates, respectively, of 4.5 hundred million, 6.1 hundred million, and 6.9 hundred million times per millionth of a second.

6. Effects of Motion of Molecules.—One of these, diffusion, has been referred to above. Another is what has been named *osmosis.* When pores exist in a membrane in contact with a fluid, some of the rapidly-moving particles will penetrate and pass through. Now, the molecules of different liquids are moving at different rates, and also are probably of different sizes, and hence will pass through such a membrane at different rates; so that, if such a membrane separate two different liquids, more of one will pass through than of the other. Hence there will be a rise of fluid on one side and a fall on the other. This is called osmosis. For example, if a vessel full of alcohol and closed by bladder be immersed in water, the contents of the vessel will soon increase so much as to burst the bladder. If, on the other hand, the vessel contain water and be immersed in alcohol, the bladder will contract. (For similar effects produced by the electric current see § 60.)

A further effect of the vigorous motion and consequent violent collision of moving particles is that some are ruptured and their constituent atoms separated. They do not, however, long remain separated, but rapidly find partners among similarly dissociated atoms. Above a certain temperature, called the temperature of dissociation, the rapidity of dissociation may exceed that of recombination, and then the fluid is, as a whole, dissociated. The former, or temporary dissociation, at ordinary temperatures, is of great importance in the explanation of electrolysis (§ 61). That such a process is continually going on is evident from the fact that if two salts are dissolved and then mixed, new bodies, being different combinations of the atoms of the two salts, are frequently formed, and, being insoluble in the mixture, are precipitated; and this effect takes place even if the new compound is a less firmly united combination than the original salts.

7. The Form of Matter Called the "Ether."—We know any form of matter merely as an inference from the phenomena of our sense.

Now, a number of phenomena receive their only explanation by the assumption of a very exceptional form of matter called *the ether.* The evidence of its existence is therefore quite of the usual kind. Though its existence can hardly be regarded as doubtful, all the theories of its constitution are still pure speculation. Some of its properties to which we shall refer are :—

(1) It permeates all bodies and pervades all known space, even to the most distant star.

(2) It is affected by the matter of bodies in which it is. It appears to be concentrated in it to an extent depending on the density of the matter. Ether thus bound differs from free ether, in that it transmits short waves more slowly than long ones.

(3) It is continuous, not granular.

(4) Its density is to that of water as is unity to unity followed by twenty naughts (10^{20}), while its rigidity is one-billionth that of steel.

Light consists of transverse vibrations in the ether, and the rate of transverse vibration in a medium is greater the greater its rigidity and the less its density, just as the rate of vibration of a tuning-fork depends on the ratio of its rigidity to the massiveness of its prongs. Now, small as the rigidity of the ether is, it is immensely great compared with its density. Hence the immense rapidity of the vibrations constituting light,—for red light about four hundred millions per second.

Again, if the ether fills all space and is, in some respects at least, like an elastic solid, how are the heavenly bodies not retarded by it? Stokes has given a satisfactory answer, but space will only permit us to give Sir Wm. Thomson's suggested analogy: Shoemakers' wax will offer great resistance to the passage of anything through it, but bullets will pass down through it and corks float up through it, provided sufficient time be given them; the slower their motion, the less the resistance. Similarly, may it not be that the motion of the heavenly bodies is immensely small compared with the resistance of the ether?

8. Energy, Kinetic and Potential.—We now come to the second constituent of the physical universe. By energy we mean the power of doing work. Now, power of doing work resides in bodies in either of two states: (1) in virtue of their motion, *e.g.*, cannon-balls in motion will batter down a wall; (2) in virtue of their shape or position, *e.g.*, a wound-up spring will make a clock go, while a stretched spring or elastic band can, by contracting, pull up a weight. The former kind, or energy of motion, is called kinetic energy; the latter kind, or energy of shape or position, is called potential energy.

Measures of Energy.—The work a moving body can do is found to vary directly as the square of its speed, and also, of course, as its mass, and is taken as $\frac{1}{2}\,m\,V^2$. The work a deformed system can do is the force it can exert into the distance through which it can exert it, or Fs. As these are interchangeable, whenever one passes into the other the principle of the conservation of energy requires that

$$Fs = \tfrac{1}{2}\,m\,V^2$$

9. Energy of Vibrations and Waves.—In some kinds of mechanism we have a regular change of the whole energy from the kinetic to the potential form, and back again to the kinetic form, and so on. A simple pendulum gives an example of this. At the highest point of its swing it stops, and just at the moment has no velocity, and hence no kinetic energy. Its energy is all potential,—*i.e.*, it is raised up and could, in virtue of its weight, do work in descending. Again, at its lowest point its potential energy is reduced to a minimum, for it can get no lower, and what it has lost in potential energy has been transformed into kinetic energy. At intermediate points its energy is partly potential and partly kinetic.

The same is true of any kind of vibration or to-and-fro motion, whether to-and-fro motion in a straight line or to-and-fro motion of rotation, such as that of the balance-wheel of a watch.

When a vibration is handed on from part to part of a medium, each part of the medium being set into vibration as the disturbance reaches it, we have what is called a wave,—*e.g.*, an up-and-down motion started at the end of a rope will be transmitted along the rope, giving rise to a succession of waves. Hence, by the above, if we fix our attention on any part of the medium in the course of the waves, its energy will periodically change from all kinetic to all potential and back again; but if we consider a whole wave, at the crest and trough (*i.e.*, the places of greatest *displacement*) the energy will be all potential, but at the mean level the energy will be all kinetic, and at intermediate points the energy will be partly kinetic and partly potential. Considering a whole wavelength at any time, the energy will be half kinetic and half potential.

10. Subdivisions of Energy.—Though all energy we feel convinced is one, as is shown by the interchangeability of its different forms, yet the energy manifested in different classes of phenomena has received different names:—

(1) *Mechanical Energy.*—In such cases as the moving cannon-ball and wound-up or stretched spring, already mentioned, the energy is obviously due to the relative motion or position of the parts, and so may be called mechanical energy. Other kinds of energy are in reality equally mechanical, but not so obviously so, and hence are not so denominated.

(2) *Energy of Waves of Sound.*—Waves may exist in any medium, and such always possess energy. For example, water-waves can do work in the destruction of a breakwater. Sound consists of waves of compression and dilatation in the medium conveying the sound. Its energy is, accordingly, half kinetic and half potential.

(3) *Energy of Heat in Matter.*—A hot body can do work, as, for instance, by boiling water and working a steam-engine. Hence it possesses energy. In what form does this energy exist? We can say at once that it is energy of motion of the particles and of the ether in contact with the particles. The translational part of their motions gives, of course, kinetic energy, and the vibrational part varies between the kinetic and potential forms.

(4) *Energy of Light Waves in the Ether.*—Waves in the all-pervading ether, consisting of vibrations transverse to the direction in which the waves are traveling, are called light and radiant heat, going by the former name when the wave-lengths lie between $\frac{1}{30000}$ inch and $\frac{1}{70000}$ inch, and by the latter name when the wave-length lies outside of those limits. But

we may use the word light in the wider sense, so as to include both of the above divisions. Here, just as in the case of sound, the energy of the waves is half kinetic and half potential.

(5) *Energy of Chemical Affinity.*—Dissimilar atoms unite to form molecules in virtue of an attractive force between them. This force is called chemical affinity. This force of chemical affinity is too slight for consideration until the particles come within a certain range of one another, and then it comes into play and draws them together. Now, when such dissimilar atoms unite, the force is exerted through a certain distance, and hence does work. When work is done, energy is spent and reproduced in a different form; so that two uncombined atoms having a chemical affinity for one another form a system having potential energy. On combination this energy re-appears, either as heat energy, or light energy, or sound energy, or electrical energy. To separate the molecule again into its constituent atoms requires just the amount of energy that they yield up on combination, and when separated they will have just their original amount of potential energy.

(6) *Electrical and Magnetic Energy.*—At the close of this section we shall state the most likely theory as to the nature of these forms of energy.

11. Fundamental and Derived Units of Measurement.—Any property of a body, if estimated numerically, must be so estimated by comparing it with a standard or unit of the same kind. Now, all bodies occupy space and possess mass, and hence we must have units of space and mass. If we have to consider motion or change of any kind the element of time will enter. The units of length, mass, and time are the fundamental units, and may be arbitrarily taken as anything we please. The English have chosen the pound, the foot, and the second, being fixed by arbitrary definition. The French have chosen the centimetre, the gramme, and the second, equally arbitrarily defined. These French units are the most convenient because they are decimally subdivided and multiplied, and hence are the ones usually employed for scientific purposes. They are shortly denoted as the C. G. S. system. For translating from one system to the other the following values may be usefully remembered: A *metre* = 100 centimetres = 39.37 inches; or an inch = 25.4 millimetres = 2.54 centimetres. Again, 1000 grammes make a kilogramme. Half of the latter, called a demi-kilo, is the ordinary commercial retail standard used in France, and is roughly equal to a pound,—more exactly, = 1.1 ℔. Hence a gramme = .0022 ℔.

Derived Units.—For measuring other properties, units derived from the above are employed. The unit of velocity is a velocity of unit length per unit time, or, in the C. G. S. system, a velocity of a centimetre per second. *Acceleration* is the rate of increase of velocity, and the unit of acceleration is, therefore, defined in terms of the unit of velocity and the unit of time. It is an increase of unit velocity in unit time, or, in the C. G. S. system, an increase every second of a velocity of a centimetre per second. A *force* is whatever produces or changes motion in matter, and hence the *unit of force* is defined in terms of the units of acceleration and mass, as the force which produces unit acceleration in unit of mass. In the C. G. S. system it is called the *dyne*. The dyne, therefore, is a force which every second increases the velocity of a gramme mass by one centimetre per second, or, stated more briefly,

gives a gramme mass an acceleration of one centimetre per second per second. Work is done when a force acts through some distance, and is measured in terms of the force exerted and the distance through which it acts. The C. G. S. unit of work, or the work done by a dyne when exerted through a centimetre, is called the *erg*.

12. Subdivisions of Electricity.—For convenience of treatment electrical phenomena have been divided into three departments: (1) static (or franklinic) electricity, (2) kinetic (or voltaic) electricity, (3) induced (or faradic) electricity. In addition to these there is the subject of magnetism, which will be treated of between (1) and (2).

Static (or Franklinic) Electricity.

13. Definition.—As our ideas are still very dim and vague as to what electricity is, we can at the outset only define the thing we are going to study as that which is made manifest in a certain way and has certain properties. If a dry glass rod be rubbed with silk it is found to have the property of attracting light bodies such as pieces of paper and bits of pith. That which is made manifest by this rubbing, whether it is a thing, or a state, or whatever it is, we call electricity, and the rod is said to be electrified. But if we try a number of different substances to rub the glass with, or a number of different solids instead of glass to be rubbed, we shall find the same thing true. In all cases electricity is manifested. For example, we shall find the property strong when the rubber is of flannel and the stick of sealing-wax.

14. Two Kinds of Electricity.—So far as its action on light bodies —say, a pith ball suspended by a silk string—is concerned, we shall find the electricity shown in all the above cases quite the same. The pith ball is in all cases first attracted by the electrified glass, touches it, and is then repelled by it. The same is true of the electrified sealing-wax. But a difference will soon be discovered. It will be found that after touching the glass the pith ball is repelled by the glass but attracted by the sealing-wax, and after touching the sealing-wax it is repelled by the sealing-wax but attracted by the glass, so that it may be made to vibrate between the two.

Hence we are compelled to recognize two kinds of electricity. These are often called *vitreous* (like that found on glass after rubbing by silk) and *resinous* (like that found on sealing-wax after rubbing by flannel). There are no more than two kinds, for the electrified pith ball is in all cases either attracted or repelled by an electrified body. When we come to discuss what the real nature of electricity is we shall find that there may really be only one kind; that, in fact, electricity is a thing, and that vitreous and resinous only describe different states of that thing. A very old theory associated with the name of Franklin is that the vitreous form is merely an excess of that thing and the resinous a deficiency of it; and so another pair of names have arisen, namely, *positive* instead of

vitreous and *negative* instead of resinous. Though not committing ourselves in any way to this theory, we shall usually employ these terms, positive and negative, for in another respect they are specially happy terms. In algebra positive and negative are opposed terms and mean that two quantities of the same size, one being positive and the other negative, when simply added together amount to zero. We shall find the same true of the two electricities after we have defined what we mean by a quantity of electricity.

15. Hypothesis Provisionally Adopted.—We do not stop here to settle whether all electricity is of one kind or whether there are two kinds. The former theory, stated by Sir William Watson and elaborated by Franklin, is called the " one-fluid " theory. The latter, associated with the name of Sumner, is called the " two-fluid " theory. Its terminology is the most convenient for the description of electrical phenomena, and we shall adopt it as our working hypothesis, though we shall altogether avoid the term fluid and simply speak of two kinds of electricity. To state it at fuller length, it is this :—

(*a*) There are two kinds of electricity.

(*b*) Like kinds repel each other, unlike kinds attract each other.

(*c*) An unelectrified body contains equal quantities of the two kinds, inexhaustibly large, and these two kinds can be separated, to a greater or less extent, by friction or the action of other electrified bodies.

(*d*) The attractions and repulsions mentioned in (*b*) are weaker the greater the distances between the electrified bodies. (More precisely, they decrease in proportion as the square of the distance increases.)

The explanation this theory gives of the pith-ball experiments is the following: When the electrified glass rod is brought near to the pith ball, the positive electricity of the rod separates the combined electricities of the pith ball, attracting the negative and repelling the positive in accordance with (*b*), so that the side of the ball nearer the rod is negatively and the side farther away positively electrified. The negative charge being nearer the rod than the positive one is, by (*d*), more strongly attracted than the positive charge is repelled, and the final result is attraction.

Induction.—This separation of the electricities of an unelectrified body by the action of an electrified one is called induction. On touching the rod the negative electricity of the ball is neutralized by an equal quantity of the positive of the rod, and so the ball is left positively charged. To explain the action of an electrified sealing-wax rod on a single pith ball we have only to interchange the words positive and negative in the above. After contact with the glass rod the pith ball is positively charged, and hence is attracted by the negatively-charged sealing-wax. In the above it has been assumed that equal quantities of the two kinds of electricity are always produced. This will be referred to later, and experimental proof given (§ 17).

16. THE GOLD-LEAF ELECTROSCOPE.—A much more convenient apparatus for detecting the presence of electricity than the pith ball spoken of is a pair of strips of gold-leaf hung from a metal rod inside of a glass jar, the metal rod having a metal disc at the top. This is a sensitive instrument for indicating the presence of electricity and testing its kind; for, on bringing an electrified body over the disc the electricities of the disc are separated, unlike electricity being attracted by the electrified body and like electricity being repelled to the gold-leaves. The leaves accordingly, being similarly charged, repel one another, and therefore diverge. This divergence will be greater the greater the electricity repelled to the leaves; that is, the greater the charge of the body being examined. Thus, the instrument is a detector of electricity.

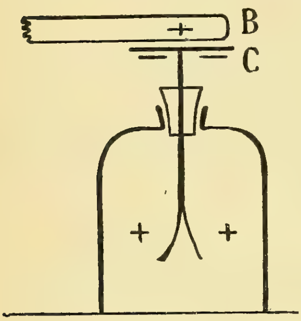


FIG. 1.

Further, it can be used to test the nature of a charge; for, if while it is subject to the inductive influence of a charged body the plate, C, be touched by the hand, the leaves immediately collapse. The explanation of this is, that the charge of the leaves escapes through the hand, while the charge on the plate is still kept "bound" by the attraction of the charged body which is being tested. Then, when the charged body is removed, the charge formerly "bound" on the plate is set "free" and spreads over the leaves also, so that they again diverge, but this time with electricity of the opposite kind to that of the original inducing charge.

Now, to test a charge by the electroscope: Suppose the inducing body, B, was positively charged, then the final charge of the leaves was negative. If, now, a negatively-charged body be brought near the plate, it will repel still more negative electricity to the leaves, and so cause them to diverge still more; but if a positively-charged body be brought near the plate, it will repel positive electricity to the leaves, and so cause them, at first at least, to diverge less. If, however, the positively-charged body be sufficiently strongly charged, it may just repel enough positive electricity to the leaves to neutralize their negative charge, so that they collapse; and then, when brought still nearer, it will repel still more positive electricity to them, so that they again diverge, but this time with positive electricity. Thus, it is the initial movement of the leaves that must be observed.

Hence, when the leaves are left negatively charged, they will expand more when a negative charge is brought near the disc, C, but less when a positive charge is brought near it.

17. EQUAL QUANTITIES SIMULTANEOUSLY DEVELOPED.—By means of the above delicate instrument we can prove the point referred to at

the end of § 15. A flannel cap is made for a rod of sealing-wax. A dry silk thread attached to the cap enables us to turn the cap without touching it. If the rod be turned inside the cap, and then drawn out and presented to the electroscope, it will be found to be negatively electrified; the cap, on being presented to the electroscope, will be found to be positively electrified. But if the rod be turned several times inside the cap and then, without drawing the cap off, both together be presented to the plate of the electroscope, no effect on the leaves is observed. Hence, the two electricities are developed simultaneously and in equal quantities; and this is found to be always so.

18. Electricity Obtainable from All Bodies.—Having shown that as an effect of rubbing in certain cases equal quantities of the two kinds of electricity are obtained, the question arises, Is it only from a limited number of bodies that electricity can be so obtained? Apparently so; for a metal rod rubbed will show no effect on the electroscope. But may it not be always developed by rubbing, and in some way escape our notice? May it not leak away before being noticed? Through what substances will electricity leak? This can be most readily tested by the electroscope: having charged it, touch it with the finger; the charge escapes. Touch it with a metal wire; the charge escapes. Touch it with a dry silk thread; the charge does not escape. Wet the silk thread; it escapes. Try a dry glass tube, it does not escape; try a linen thread, and it does escape. Hence, electricity moves along some bodies, not along others. The former are called *conductors*, the latter *non-conductors* or *insulators*.

This naturally suggests that a metal rod, if insulated and rubbed, would be found electrified. Such will be found to be the case; for, if a brass rod be attached to a glass handle and rubbed, it will affect the electroscope. Electricity, in fact, can be obtained by the friction of any two bodies, though stronger charges will be obtained from some pairs of substances than others.

But we can go farther than this. We can arrange all substances in regular series, a glance at which will tell us what will happen if we rub any two substances in it together. This series is called Volta's contact series. It is such that if any two substances in it be rubbed together, the one that comes higher in the list will be positively electrified and the other negatively. The following will illustrate what is meant:—

+ Catskin.
Flannel.
Ivory.
Rock-crystal.
Glass.
Cotton.
Silk.
Metals.
Sealing-wax.
Resin.
Sulphur.
Gutta-percha.
— Gun-cotton

19. Conductors and Non-Conductors.—These are only relative terms. No absolute non-conductors are known and no perfect conductors. But when we have defined conducting power more exactly we shall find a

great difference between substances as regards their conducting powers. Hence bodies that conduct well are called conductors, and those that conduct so extremely ill that under ordinary circumstances they may be regarded as devoid of conducting powers are called non-conductors or insulators.

The following are conductors: Metals, graphite, flame, linen, cotton, moist bodies generally, etc.

The following are non-conductors: Ebonite, resins, shellac, amber, caoutchouc, dry gases, sulphur, glass, silk, wax, etc.

20. Machines for Obtaining Electricity by Friction and Induction—The Electrophorus.—Having thus the means of obtaining electricity in small quantities, all we need to get a good continuous supply is to apply mechanical devices to working these sources of electricity. Full descriptions of these machines and their treatment will be found under the section treating of "Franklinic Electricity," to which the reader is

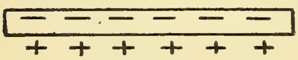


Fig. 2.

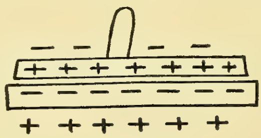


Fig. 3.

Fig. 4.

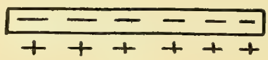


Fig. 5.

referred. The principle on which they are all founded will be readily grasped from the following brief description of the very simplest of them,—the electrophorus.

The electrophorus consists of a shallow pan of metal (called the *sole*) containing a cake of wax (resin or ebonite), and a circular disc of metal of somewhat smaller diameter than the pan, and provided with an insulating handle. This is called the cover. It is used as follows:—

(1) The cake is dusted with a piece of flannel, after which the surface of the cake is found to be negatively electrified, and by induction a positive charge is drawn to the metal of the sole. (Fig. 2.)

(2) The cover is now brought down on the cake, and thereby a positive charge is induced on the metal cover. (Fig. 3.)

(3) The cover is now touched with the finger, whereupon the repelled negative charge of the cover escapes. (Fig. 4.)

(4) The cover is now removed and carries away a positive charge with it, leaving the cake exactly in its first condition, making allowance for a slight amount of leakage of its charge that has nothing to do with the process. (Fig. 5.)

All we need to do now is to mount the cover and sole on rotating plates in such a way that when the plates are rotated, by hand or otherwise, the cover is brought into the presence of the sole, touched, to carry

away its repelled charge, and then carried around to another body, to which it imparts its charge, and again brought around in front of the sole. Thus we shall have a *continuous electrophorus* yielding supplies of both kinds of electricity.

An important point may be noticed in the foregoing description. The charged cover when removed contains a stock of energy, as is shown by the noise and sparks it will yield on giving up its charge to another body. Whence came this energy? Not from the cake, for its charge is not at all diminished by the operations. To produce energy work must be done or energy expended. The source of the energy of the charged plate is the *extra* work that must be done, in lifting the cover away from the oppositely charged cake, over and above what would be done if the cake were not charged. Similarly, in a continuous machine more work is done in rotating the parts when the machine is charged and working than would be done if the machine were not charged, and this extra work is the source of the energy.

The above must not be understood as implying that electricity is energy. It is not, though electrification is. But, of this later.

FIG. 6.

21. DISTRIBUTION OF ELECTRICITY ON CONDUCTORS.—On a non-conductor electricity remains where developed, but on a conductor it spreads itself, though not uniformly. The charge on a small part of the surface is greater the more curved it is. The charge per unit of surface is what we define as the *surface density* of the electrical distribution. It will be noticed that we speak only of the surface density, and in truth this is all that we need speak about, for electricity resides only on the surface of conductors. No charge whatever can be detected, except on the surface. The charge of electricity a conductor will accept depends in no way on how the interior of the conductor is constituted, whether it be hollow or filled in any possible way. This can be shown in many ways. Biot showed that when a ball is charged and covered by two metal hemispheres with insulating handles, then, after the hemispheres have touched the ball and been removed, no charge remains on the ball. Faraday proved it by showing that if a small, conical net be charged and then turned inside out by means of a silk thread through the vertex, the charge always resides on the outside.

22. THE STATIC UNIT OF ELECTRICITY.—Electricity is that which produces certain attractions and repulsions, and is to be therefore defined in terms of the force of these attractions and repulsions. Let us think of two equal quantities of positive electricity at two points a unit dis-

tance apart, and let these quantities be such that they repel each other with a unit of force. Then, either of these we shall take as our unit of electricity; or, the static unit of electricity is such a quantity that when at unit distance from another equal quantity it repels the latter with unit force.

23. THE ELECTRICAL FIELD.—An electrical field is the portion of space in the neighborhood of electrified bodies considered with reference to electrical phenomena. At every point in an electrical field there is an electrical force,—*i.e.*, a small charge of electricity introduced there would be urged with a definite force in a definite direction. The force with which a positive unit would be urged is called the electrical force or the field-strength at that point. To specify fully the force at a point in the electrical field, we must give both the magnitude of the force and its direction. If, starting from any point, a curve be drawn following everywhere the direction of the electrical force at the points through which it passes, such a curve is called a line of electrical force; or, a line of electrical force is a line whose direction at every point is that of the electrical force.

24. POTENTIAL.—The conception of potential is one of the most important in the treatment of electricity. Unfortunately, it is also one that has acquired the reputation of presenting considerable difficulty to the uninitiated. This evil reputation it probably owes to a certain confusion in the way in which it is frequently explained. To understand it clearly we must remember clearly the difference there is between the *idea or meaning* of a physical property and its *measure*. The idea can be but one, though the modes of measurement may be many.

To make clear what we mean let us think of the word mass. By the mass of a body we mean simply the quantity of matter it contains. But when we proceed to measure the mass we may employ several methods. We may compare masses by comparing the speeds that a certain force —say, a stretched elastic string—drawing them along a smooth horizontal table will get up in them. Then, by a well-known law due to Newton, the masses are inversely as the speeds thus produced by the same force. Again, we may compare the masses by comparing the forces with which they are attracted by the earth. Thus we measure them by weighing them in a balance. These methods lead to the same result, and are therefore consistent. Others might be given, but these will suffice to make clear the distinction referred to.

Let us take another and more closely parallel case, viz., temperature. The idea of temperature is simply this: Of two bodies, that is said to be at the higher temperature which will yield up heat to the other when the two come into contact; or, temperature is that quality which determines the direction of flow of heat when two bodies are put in contact. Now, we may *measure* this property in various ways,—*e.g.*, the higher the temperature of a mass of mercury, the greater is found to be its volume.

Hence we compare temperatures by the height to which mercury rises in a closed tube. This is the method of the mercury thermometer. Again, if we take a spiral spring made out of a ribbon, consisting of a strip of platinum and a strip of silver, it will be found that the higher its temperature the more it will untwist, and so turn a light needle, which will indicate the temperature. Thus, temperature bears but one meaning, but the property can be measured in different ways.

The idea of potential is like that of temperature, viz., the quality that determines the direction of flow of positive electricity when two charged bodies are brought into communication by a conductor. The one from which the positive electricity flows is said to be at the higher potential.

The measure of potential usually adopted can be best made clear by the aid of another analogy. Potential of electricity is like the level of water. The level of water is that which determines in what direction water will flow when two vessels are put into communication, the surface being at the higher level in the one from which water flows. Now, it is true that we have a foot-rule method of measuring difference of level. But without the foot-rule we might have measured it in this way: When a pound of water is raised from a lower to a higher level the attraction of the earth is overcome through a certain distance and work is done, the measure of the work being the product of the force overcome and the distance, so that for different differences of level the work done is proportional to the difference of level. Thus, if we had an instrument for measuring the work we could in this way measure the difference of level.

Now, electricity is an invisible thing, not material,—at least, in the ordinary sense of matter; so that we cannot apply anything like a "foot-rule" method to measuring differences of potential; but we can apply the work method, and then we give the following definition: The measure of the difference of potential of two charged bodies is the work that would have to be done in carrying a unit quantity of positive electricity from the one of lower to that of higher potential.

To understand this definition clearly, there are several things to notice about it. In the first place, it implies a unit of difference of potential, namely, unit difference of potential is the difference of potential that exists between two charged bodies when unit of work is required to carry unit of positive electricity from one to the other. In the second place, it will be noticed that we have spoken only of *differences* of potential. In fact, this is all we have to deal with, just as it is only with difference of water-level that we have to do, though some standard level or starting-point for the measurement of level may be most convenient. In the case of water, the starting-point usually taken is the level of the sea. Similarly, the most convenient practical starting-point in measuring differences of potential is that of the earth or anything in electrical

communication with it. Hence, the practical zero of potential is that of the earth. But there is a theoretical or absolute zero of potential employed in the mathematical treatment of electricity, namely, the potential at an infinite distance away from a charged body. This absolute zero, however, need not be employed in this work, just as the practical zero of temperature—that of melting ice—suffices for all practical purposes, though an absolute one is employed in theory, being about 273° C. below zero. Further, it will be noticed that the above definition applies, no matter what unit of electricity is employed. Now, some slight confusion and difficulty are caused in electricity by the fact that two different units are at different times employed. One we have explained (§ 22); the other, and more important one, we will explain later.

Finally, though the above definition applies only to the difference of potential between two charged bodies, it need not be limited to two charged bodies, but may be made to apply equally to two points. It is evident that if two points are in the neighborhood of charges,—*i.e.*, are in an electrical field (§ 23),—work will be needed to carry electricity from one to the other, and they will therefore be at different potentials. Hence we shall often have to speak of the differences of potential *between points.*

25. Capacity.—If we put an insulated conductor close to the discharging knob of an electrical machine supplying, say, positive electricity, the knob will, for a time, discharge positive electricity to the conductor, but will soon cease to do so. But if we now bring the conductor equally near to another machine giving electricity at a higher potential, a further charge will be imparted to the conductor. In fact, with a source of electricity at a given potential there is a certain maximum charge that can be given to a conductor, for no more can be imparted when the charge on the conductor has risen to the potential of the source.

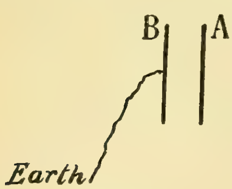


Fig. 7.

How much electricity is required to raise the charge on a conductor to a given potential depends on the capacity of the conductor. The capacity of conductors corresponds to the breadth of jars containing liquids, for it is the breadth that determines the amount of liquid requisite to fill a jar to a given level. Hence we define the capacity of a conductor as the quantity of electricity requisite to increase its potential by unity.

26. Condensers.—A condenser is simply a means employed to increase the capacity of a conductor, *i.e.*, a means of getting a larger charge on the conductor, the potential of the source being unchanged. If the conductor mentioned in the last paragraph be a circular disc of metal, A, and if a second similar one, B, connected with the earth, be brought near the first, but not so as to touch it, it is found that the

first one will receive a much greater charge than previously from a source at the same potential. This combination of two plates with an insulator (in this case air) between them forms a plate-condenser (Fig. 7).

The effect of the second plate, B, can be explained thus : The potential of A being raised, A tends to raise the potential of B; but B remains at the potential of the earth, since it is connected with it by a conductor. Hence, negative electricity must flow to B from the earth; so that the negative potential so caused may just neutralize the positive potential that A would cause, and would leave B at zero potential. The negative potential thus produced by B's negative charge then reacts on A, tending to lower its potential, but its potential does not fall, being the same as that of the terminal of the machine. Hence, more electricity must flow to A from the machine to keep its potential up. Thus the effect of the second plate is to enable A to receive a larger charge, *i.e.*, to increase its capacity.

27. Dielectrics and Inductive Capacity.—The above interaction between A and B is, of course, only possible when the medium between A and B is non-conducting. A non-conducting or insulating medium between two electrified conductors is called a *dielectric.* In the above case it was air, but it might have been glass, ebonite, or any other insulator whatsoever. We should find, however, a difference between different dielectrics. For equal thicknesses of the dielectric, glass as a dielectric would give a condenser of three times the capacity that air would, and solid paraffin two times. This quality of an insulator that determines the capacity of a condenser in which it is employed as dielectric is called its *inductive capacity.*

To be more precise, we must assign a method of measuring the property called inductive capacity. It can be done in this way : Determine the capacity of a condenser in two sets of circumstances,—first, with air as its dielectric ; second, with, say, glass as its dielectric. Divide the capacity of the condenser in the latter case by its capacity in the former, and the ratio is called the specific inductive capacity of the glass. The ratio so determined will be found to be the same, no matter what shape or size of condenser is employed. It depends only upon the dielectric. Hence, the *specific inductive capacity* of a dielectric is the ratio of the capacity of a condenser with that substance as dielectric to that of another exactly similar but with air as dielectric.

Note.—The reader must be careful not to confuse the terms *capacity of a condenser* (§ 25) and *inductive capacity of a dielectric.*

28. Forms of Condensers.—It is evident from § 26 that, if the thickness of the dielectric of a condenser be decreased, the inductive effects will be increased, and so the capacity of the condenser increased. Again, it is evident that increasing the area of the plates will also increase the capacity of the condenser. Hence, on the whole, the capacity of a condenser is proportional (1) directly to the area of the plates ; (2)

inversely to the thickness of the dielectric; (3) directly to the specific inductive capacity of the dielectric.

Condensers are made in many forms. The usual dielectric is glass, for its specific inductive capacity is particularly high. The jar form of condenser is the most common and most convenient. It is simply a glass jar coated with tin-foil two-thirds of the way up, inside and outside, and closed with a cork, through which a metal rod passes carrying a knob at the upper end, and connected at its lower end with the internal coating. To charge it, the knob is connected with a machine and the outer coating with the earth. It will thus charge to the potential of the machine; but if the latter be too high, the glass is apt to be broken by a disruptive discharge through it. Such condensers are used in connection with the terminals of machines to enable them to store up larger quantities of electricity, and thus cause a larger discharge. (*Vide* also section on "Franklinic Electricity.")

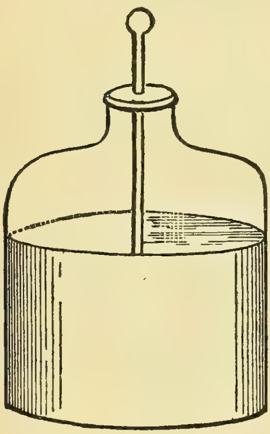


FIG. 8.

29. SEAT OF CHARGE AND RESIDUAL CHARGES.—At the end of this section we shall make a short attempt to explain what electricity is, and so we state here a few facts as to the action of Leyden jars that bear on that point. If a jar be made with stiff, removable coatings and charged, it will be found, on removing the coatings, that no charge really resides on them; and yet, on restoring them and discharging the jar, the original charge will be reproduced. Such, however, will not be the case if the glass of the jar be thoroughly discharged by passing it through a flame while the jar is apart. Hence the charge, whatever its nature, really resides in the dielectric.

Again, after an apparently complete discharge of a jar a residual charge is slowly developed, as may be seen by again discharging it, whereupon a small discharge will be obtained. This has been described as a "soaking" of the electricity "into" the dielectric, and a subsequent "soaking out." Its real nature will be discussed later.

Again, every charge has its corresponding residual charge and discharge; so that if several charges be given to a jar, the charges being either of the same or of different kinds, all the residual charges can be obtained, but in the opposite order to the order of the original charges. This is an exact parallel to certain phenomena obtained by twisting an elastic rod. If such a rod be twisted, and then allowed to gently untwist, it will not do so completely, but will retain a residual twist and will show a residual untwisting. Moreover, if the rod be given several such twists,

whether in the same or in opposite directions, corresponding residual twists and untwistings also take place in the opposite to the order of the original twists.

Now, these latter are due to elasticity in the rod; and the similar action of the Leyden jar, taken together with what was stated as to the seat of the charge, suggests that electrification is an elastic phenomenon of the dielectric, or of something associated with it. Of this, later.

Magnetism.

30. We turn now to certain other phenomena long thought quite distinct from the preceding, but which fundamentally are closely allied. We shall take them up from the point of view of this connection. If a copper wire be bent into a spiral around a glass tube covering a steel rod, such as a knitting-needle, and a charge of electricity—say, from a Leyden jar—be passed through the spiral, the steel rod will be found to

Fig. 9.

have acquired certain new properties. These properties are called magnetism, and the rod is called a magnet. The properties are these:—

(*a*) If freely suspended in a horizontal plane, the magnetized needle will take up a definite nearly north and south direction, to which it will return after being disturbed. The end pointing nearly north is called the north-seeking pole of the magnet, the other the south-seeking pole.

(*b*) If two such needles be suspended near each other, it will be found that like poles repel each other and unlike poles attract each other.

But these two properties are not distinct. The first to show this was Gilbert, of Colchester ("the Galileo of Magnetism"), who lived in the sixteenth century. For the earth itself is a magnet, and consequently acts on other magnets according to (*b*). The magnetic action of the earth can be fairly well represented by imagining a great magnet, about half the earth's diameter in length, buried, with one end below Boothia Felix, in the north of Canada, and the other at the opposite point in the southern hemisphere. It will now be seen that if we call that pole of this great earth-magnet which lies in the northern hemisphere the magnetic north pole of the earth, we should properly call the north-seeking pole of a magnetic needle a true south pole, and the south-seeking pole a true north pole. But custom is quite inconsistent in this matter; so we shall have to adhere to the terms north pole and south pole of a magnet, meaning thereby north-seeking and south-seeking, respectively.

31. Magnetic Induction, Temporary and Permanent.—Supposing that in the preceding way a magnet has been produced, we can from that magnet make others, as follows: Take another unmagnetized steel

needle and stroke it from end to end, always in the same direction, with the north pole of the magnet. It will be found that the unmagnetized needle has become magnetized with a south pole at the end which the north pole of the magnetizing needle last touched. In this way any number of *permanent* magnets can be made by induction.

But *temporary* magnetism can also be induced. Of this we have an example in the familiar experiment of shoving a pole of a magnet among soft-iron filings, whereupon the filings cling to the pole. This is simply due to the fact that the iron particles become, for the time being, magnets attracted by the inducing pole and attracting each other; but immediately the inducing magnet is removed they cease to attract one another; their magnetism is gone. This merely temporary induction of magnetism in soft iron is of great importance. It will be noticed that the difference is that hard iron or steel is susceptible of permanent magnetism, soft iron of merely temporary magnetism.

The oldest known example of induction is the inductive action of the earth's magnetism on a certain compound of iron called magnetic iron-oxide, giving rise to the lodestone, which is supposed to have been named magnet from being found in Magnesia, in Asia Minor. Being itself a magnet, it can be used to magnetize a needle, and in this way the first mariners' compass was produced. There seems little doubt that the Chinese knew and used this property four thousand years ago (see Sir Wm. Thomson's "Popular Lectures," vol. iii, "Navigation").

32. Unit Magnetic Pole; Laws of Magnetic Attractions and Repulsions; Magnetic Field.—The definition of unit pole is like that of unit charge of electricity, viz., unit magnetic pole is that which at unit distance from an equal similar pole repels it with unit force. Having thus defined unit pole, the laws of magnetic attractions and repulsions may be stated thus :—

(*a*) Like poles repel one another, unlike attract.

(*b*) The attractions and repulsions are proportional to the strength of the poles.

(*c*) The attractions and repulsions are inversely proportional to the square of the distance between the poles.

These are the same as for quantities of electricity, and need not be enlarged on.

A magnetic field is the portion of space in the neighborhood of magnetized bodies considered with reference to magnetic phenomena. The strength of the field at any point is the force with which the field would act on a positive unit pole at that point. A line of magnetic force is a line whose direction at every point is that of the direction of the magnetic force. Magnetic potential will probably not be referred to in the sequel; so all that need be said of it is that it is measured like electrical potential (§ 24).

33. Astatic Combination of Magnetic Needles.—Any freely-suspended needle is subject to the directive force of the earth. If a quite

similar needle be attached to it so that similar poles point in opposite directions, and the combination be freely suspended, the needles will, under the earth's influence, tend to turn in opposite directions; and if the needles be perfectly similar and of equal strength, the earth will exercise no directive force on the combination,—or, it will be astatic. But as it is practically impossible to get a perfectly similar pair of needles, we must content ourselves with a nearly astatic combination; that is, a combination on which the earth exercises but a very feeble directive force. Such a combination is useful for purposes that will be stated later.

34. Facts Bearing on the Nature of Magnetism—Molecular Theory.—If a magnet—say, a magnetized piece of watch-spring—be cut in two, it will be found that each piece is a magnet with two opposite poles. The same holds true no matter how often we may cut a magnet up or how small particles we may reduce it to. Hence, magnetism is a property of the ultimate particles of a substance.

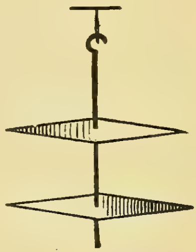


Fig. 10.

In an unmagnetized needle these little molecular magnets lie higgledy-piggledy,—in all directions,—and magnetization consists in turning them so as to face in the same direction. When a piece of iron is fully magnetized or saturated,—*i.e.*, has received the full measure of magnetism it can contain,—all these molecular magnets have faced in the same direction; when magnetized below saturation, some have wheeled around and some have not, or all have wheeled around, but not the whole way. Thus, in the body of a magnet, each north pole will be neutralized by an adjacent south pole belonging to a neighboring molecule. The unneutralized north poles at one end give a north pole to that end of the bar, and the unneutralized south poles at the other end a south pole there. This is the molecular theory of magnetism.

Some facts bearing on it may be mentioned. It is evident that on this hypothesis magnetization should be facilitated by anything that tends to set the molecules in motion; and on the other hand, after the magnetizing agent has ceased to act, demagnetization should be accelerated by the same means. This is found to be so. Hammering, twisting, and bending tend to set the molecules free, and thus aid magnetization or demagnetization, as the case may be. Moreover, heating, which consists in giving more vigor to the molecular motions (§ 10), also assists in a similar way.

Again, if such a wheeling into line actually takes place, we might expect to find a change in the length of a bar on being magnetized. This is a well-marked phenomenon amounting in certain cases to $\frac{1}{200000}$ of the whole length of the bar.

Finally, strong support is given to the theory by the action of a

model, consisting of a large number of small magnetic needles, constructed recently by Ewing. This would not be the place to go into details. Suffice it to say that the most of the peculiar stages of magnetization and demagnetization of a bar are imitated by his molecular model.

Kinetic (or Voltaic) Electricity.

35. Currents of Electricity.—We proceed now to consider the properties of streams or currents of electricity. But it will be understood that the electricity we have to do with differs in no way in kind from that which we have already treated of, though it does differ at first sight as regards method of production, and certainly differs greatly in potential and quantity. Static electricity as produced by the machines referred to in § 20 is electricity at very high potential, but very small in quantity. The electricity we get by the contrivance described below is electricity at very low potential, but in large quantities. Or, if we compare the stream of electricity between the knobs of a statical electrical machine and the current of electricity produced by a voltaic pile, the difference between them is like that between a lofty water-fall down which a small stream falls and a broad, slow river of small pitch. In both of the latter cases it is water, and so too in both of the former cases it is electricity.

Volta's cell for procuring a current of low-potential electricity is this: Take a zinc and a copper plate, connect them by a wire and dip them into water containing a small proportion of sulphuric acid. Immediately bubbles will begin to be given off from the copper plate. Moreover, a new property has been conferred on the wire; for if it be wound in a spiral around a glass tube containing a piece of soft-iron wire, it will be found to make the latter temporarily a magnet; hence a current of electricity is passing along the wire. But this method of showing the presence of a current is one far from satisfactory or handy; so we must proceed to explain a much better one.

36. Indicator of Current; Oersted's Principle; Galvanometer. —The following connection between a current of electricity and a magnet discovered by Oersted goes by the name of Oersted's principle, viz., a freely-suspended needle in general is deflected by the passage of a current of electricity in its neighborhood. This may be readily tested by an electrical machine and a freely-swinging needle. On sending positive electricity from *south to north* over the needle it will be found to deflect with its *north end west*, and reversing the direction of the current, or changing from above to below, will reverse the direction of the deflection. The direction of the deflection will always be given by the following rule: Suppose yourself swimming in the current and facing the needle, then the north pole will be deflected to your left hand. This is Ampère's rule. A simpler one is: Place your right hand on the current with the palm toward the needle, then the north pole of the magnet will be deflected in the direction of your thumb.

A sensitive needle will thus serve to detect a current of electricity. But we can greatly increase the sensitiveness of the test as follows: Instead of using a single straight portion of the wire, let us make a circular coil of part of it and put the needle at the centre of the coil, and in its plane. Then each part of the current will act on the needle, and, since the current circulates several times around the needle, the effect will be correspondingly multiplied. Such a contrivance was originally called a multiplier, but it is identical in principle with the present-day galvanometer.

FIG. 11.

To render small deflections of the needle visible several devices have been employed. Sometimes a long, light pointer (say, of aluminium) is attached to the needle. The motion of the end of the pointer is greater in proportion to its length than that of the needle, and so small deflections are made more evident.

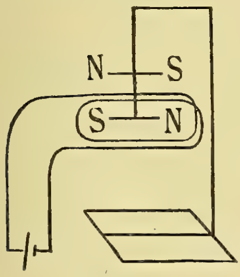


FIG. 12.

A much more effective device, due to Poggendorff, is to attach a very light mirror to the needle and allow light to fall on the mirror and then be reflected to a somewhat distant scale. It is a simple matter of geometry to show that the direction of the reflected ray is turned by the motion of the mirror through twice as great an angle as the mirror is turned through by the passage of the current. This is what is known as *Thomson's reflecting galvanometer.*

Another means of making the galvanometer a more sensitive detector is to use an astatic combination of needles (§ 33), letting the current circulate around one of the needles only. Thus, the earth's directive force being greatly reduced by the pitting of one magnet against the other while the directive force of the current is undiminished, since it acts on one needle only, the astatic pair will answer much more sensitively to the passage of a current. This gives us the *astatic galvanometer*. Or, a single needle may be used and the earth's directive force counteracted by a large, stationary, compensating magnet, M, producing a field in the opposite direction to the earth's field. By this device the mirror can be turned so as to reflect in any desired direction. Such means as these give very sensitive instruments for detecting the presence of currents.

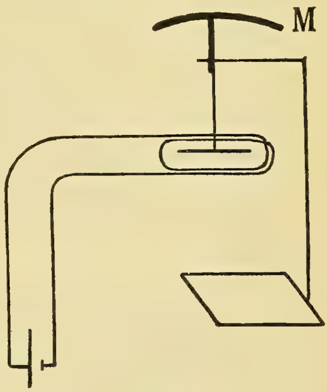


FIG. 13.

37. Volta's Cell.—If the plates of Volta's cell, described in § 35, be connected with the ends of the galvanometer coil, an immediate deflection of the magnet announces the passage of a current of electricity. If instead of a galvanometer a simple needle be used, a straight portion of the circuit carrying the current being held over it, it will readily be seen, from the direction of the deflection of the needle, taken along with the

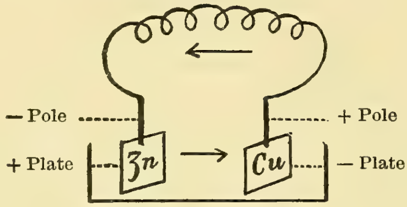


Fig. 14.

rules given in § 36, that the positive current goes from the copper plate along the wire to the zinc plate, and thence from the zinc plate in the liquid to the copper plate. (As a *memoria technica*, the rule *zinc in liquid to copper* may be shortened to *z-in-c*,—spelling the word zinc.)

Terminal wires or binding-screws are usually attached to the plates. Now, considering the external part of the circuit (*i.e.*, the part out of the liquid), the positive electricity passes from the *terminal* of the copper plate to that of the zinc. Hence the copper terminal is called the positive pole and the zinc terminal the negative pole. Considering now the part of the circuit *in* the liquid, the current passes from the zinc plate to the copper plate. Hence the zinc is called the positive *plate* and the copper the negative plate. If this be kept in mind, no confusion need be caused by the paradox that the positive pole is the terminal of the negative plate and the negative pole the terminal of the positive plate.

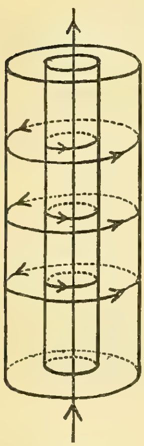


Fig. 15.

The evolution of gas at the copper plate shows that some chemical reactions are going on in the cell. What is really taking place is, that the sulphuric acid is acting on the zinc, thus:—

$$Zn + H_2SO_4 = ZnSO_4 + H_2$$

So that hydrogen is set free, and this is the gas that is appearing at the copper plate. The zinc sulphate that is formed remains in the liquid, while the zinc is gradually eaten away. This is the simplest possible form of voltaic cell.

38. Magnetic Field of Force of a Current.—Wherever a magnet is subject to magnetic force there is, by § 32, a field of magnetic force. Hence a current has a magnetic field. It is a comparatively simple problem to determine the direction of the lines of force of this

field, *i.e.*, the direction of the force at any point in the field. A magnet tends everywhere to set itself at right angles to the current, no matter on which side of the current it is. Hence, the lines of force are circles surrounding the current with their centres on the current. They may be thought of in this way : Imagine the current surrounded by circular cylinders, the current occupying the axis. Then the lines of force are circles, got by taking sections of the cylinder at right angles to the axis. The direction of the force along these lines of force relatively to the direction of the current may be found by Ampère's rule (§ 36), or it is more simply remembered from the rule that the direction of the current is related to the positive direction of the lines of force, as the thrust to the twist in a right-handed screw.

39. Electro-magnetic Units of Current and Quantity.—We have already stated the action of a current on a magnetic needle. Suppose, now, we take a wire in which a current is flowing and bend it into a circle. Let the circle be one of unit radius. Think, now, of a part of this current of unit length. It will exercise a certain force on a unit magnetic pole at the centre of the circle. What force it will so exercise will depend on the strength of the current. The unit of current that we adopt is the current which, under the above circumstances, will exert unit force on the unit magnet-pole at its centre. Or, to sum up the definition, the electro-magnetic unit of current is a current unit length of which bent into an arc of a circle of unit radius exerts unit force on a unit magnetic pole placed at the centre. If the C. G. S. units (§ 11) be employed, this is called the absolute electro-magnetic unit of current. In practice, however, a current equal one-tenth of the absolute unit of current is employed as unit, and is called the *ampère*. The electro-magnetic unit of quantity is the quantity that is conveyed by unit current in unit time. The practical unit of quantity is only one-tenth of the absolute unit, and is called the *coulomb*.

40. Electro motive Force.—When matter is set in motion or has its motion kept up in spite of resistance, we say the effect is due to a force. When a current of electricity is started or kept up in spite of resistance, we refer this effect to a force moving the electricity, or an electro-motive force. Hence, we define electro-motive force as whatever sets up or keeps up a current of electricity.

The usual cause of a flow of electricity is a difference of potential. (For a careful account of what is meant by differences of potential see § 24.) Hence, potential difference is the usual electro-motive force; but it is not the only form. Just as in the case of water the usual cause of flow is a difference of level,—but flow may be produced by other causes, such as a force-pump,—so also, in the case of electricity, other forms of electro-motive force than potential difference are known.

Now, we can readily define unit difference of potential, and we shall take the same as our definition of unit electro-motive force generally.

There is no inconsistency in this,—although electro-motive force is not always due to difference of potential,—just as there is no inconsistency in describing the pressure produced by a force-pump in a water-pipe as equivalent to a "head" of so many feet, although there may be no actual difference of level.

Hence, we shall take the unit of electro-motive force as simply the same as the unit difference of potential. The reader is therefore recommended to carefully master § 24, dealing with potential. Then, adopting the electro-magnetic unit of quantity, we define as follows: Unit difference of potential or unit electro-motive force exists between two points when it requires the expenditure of unit of work to bring a positive unit of electricity from one point to the other against the electro-motive force.

This absolute unit would be far too small. Hence the practical unit, called the volt, is taken as equal to one hundred million (100,000,000) absolute units. Although the electro-motive force of Volta's simple cell (§ 35) is not always quite the same, yet, roughly speaking, it is about a volt.

41. Resistance.—If we take the Volta cell, described on page 22, and pass the current produced by it through wires of various lengths, thicknesses, and materials, including a galvanometer in the circuit, we shall find that the current produced varies with all three of these conditions, viz., that the current is weaker the longer the wire, is also weaker the thinner the wire, and is weaker for some materials than others, even with the same size of wire. For the same length and thickness, it will be found that the current through copper wire is greater than that through an iron or a platinum one. Hence we say that iron and platinum offer a greater resistance to the current than copper does, and that long or thin wires of any material offer greater resistance than short or thick wires of the same material.

To keep this matter clear, we may remember the analogy of water passing through pipes. The longer the pipe, the greater the frictional resistance, and, the narrower the pipe, the greater the frictional resistance. Finally, with pipes of the same size, the resistance will depend somewhat on the material of the pipe. We conceive electrical resistance to be somewhat of the nature of frictional opposition to the current.

The greater the resistance of a conductor, the smaller the current that a given electro-motive force can force through it. Hence we define the unit of resistance in terms of the units of electro-motive force and current, and we say that a conductor has unit of resistance when unit difference of potential between its ends causes unit current to flow through it. If we use the absolute units of current and potential difference (or electro-motive force) this definition, of course, gives us the absolute unit of resistance. The practical unit is much larger, containing 1,000,000,000 absolute units, and is called the *ohm*. It is the resistance

of a column of mercury 1 millimetre square and 106¼ centimetres long. For convenience we tabulate these three important practical units thus :—

Unit of	called the	roughly is that of	and contains — absolute (C. G. S.) units
Current	ampère	———	one-tenth
Electro-motive force	volt	a simple Volta cell	a hundred million
Resistance	ohm	a column of mercury 1 mm. square and 1 metre long	a billion

42. Defects of the Simple Cell of Volta.—The requirements of a good Voltaic cell are so numerous that all can hardly be satisfied at once. The electro-motive force should be high and constant. Neither part of this condition is well fulfilled by Volta's simple zinc-copper cell. Its electro-motive force is not high as cells go, and not at all constant. The chief cause of its falling off in electro-motive force is what is called *polarization*, *i.e.*, a change in the surface of the plate produced by the deposition of the products of the decomposition in the cell; in this case the substance deposited is hydrogen-gas on the copper plate, by which the surface of the plate is altered ; so that we have really a different plate to deal with.

The other chief defect of the simple Voltaic cell is excessive *local action*, as it is called. By this is meant a local and useless consumption of the plates apart from the consumption necessary to produce the electric current. In the present case it takes the form of a gradual consumption of the zinc plate owing to impurities or irregularities in the plate. Wherever in the zinc a foreign particle (say, of iron) is exposed, there we have a little local battery formed by that particle, the fluid, and the adjacent parts of the zinc itself, and thus the zinc is consumed without this consumption adding to the main current. The same effect is produced by mere irregularities and inequalities in the zinc itself, for two parts of the zinc plate with slightly different physical qualities (*e.g.*, hardness) will act as separate metals, again giving rise to local action.

Local action may be got rid of by "amalgamating" the zinc plate, as it is called, *i.e.*, by giving it a surface-covering of an amalgam of zinc and mercury. This is done by first cleaning the plate with dilute sulphuric acid and then rubbing mercury over it. If the plate is one of smooth-rolled zinc it will at once take on a bright coating of zinc amalgam. The zinc consumed in the production of the current is removed from the amalgam and its place taken by fresh zinc from the plate below the coating. The action is thus rendered uniform over the surface of the plate, and any foreign particles in the zinc are brought to the surface of the

amalgam and carried away by the hydrogen bubbles. In the use of batteries containing zinc plates care must be taken to see that the zinc is kept properly amalgamated. If a battery is used daily new zinc may need to be amalgamated daily for four or five days, but after that once a week or fortnight will suffice.

To describe the remedies for polarization we would have to describe the various modifications of Volta's cell now employed. For this the reader is referred to the separate section on "Voltaic Electricity."

43. Controversy as to the Action of the Voltaic Cell.—Nearly ever since the invention of the voltaic cell a spirited warfare has been waged between two schools of physicists,—viz., the "contact" and the "chemical" schools,—as to the method of action of the cell. As in all such cases where the opponents are honest in the positions assumed, the truth probably lies between the two extremes. To make the matter plain, however, we shall state the extreme positions.

The older or contact theory is this: (1) on joining two metals, either directly or by a wire, a difference of potential is observed; (2) when the metals still joined are immersed in a liquid which acts upon one more than the other, the chemical action equalizes the potentials, and in so doing causes a flow of electricity along the connecting wire; (3) the moment the equalization of potential has commenced the difference is renewed again at the point or points of contact between the metals, and so, if no disturbing cause interfere, a continuous flow of electricity is kept up until the metal most acted on is entirely dissolved. (Gordon.)

Here, it will be noticed, the primary point emphasized is the difference of potential produced by the mere contact; but it is not claimed these differences alone will produce a current. A current will only be produced when some extraneous means—*e.g.*, chemical actions—are employed to keep up the difference. If the mere contacts without chemical reaction could produce a current there would be a constant supply of fresh energy with no corresponding disappearance of energy from elsewhere, and a consequent violation of the law of conservation of energy. Now, in a circuit consisting only of metals, all at the same temperature, no chemical actions will be observed. Hence, according to the law of the conservation of energy no continuous currents can be produced,—*i.e.*, there can be no resultant electro-motive force. To put it in the concrete: Suppose we have a circuit of three metals, a, b, c,—${}_{c}\overset{a}{\nabla}{}_{b}$,—and suppose we call the electro-motive forces at the contact, respectively, F_{ab}, F_{bc}, F_{ca}, reckoning them all in the same direction, then, since there is no current,

$$F_{ab} + F_{bc} + F_{ca} = 0;$$

and the same will be true, no matter how many different metals may be included in the circuit.

We can put the above in another way; in fact, the way in which it

was originally put by Volta himself. Of course, the electro-motive force from a to c is equal, but of opposite sign to that from c to a; or, $F_{ac} = -F_{ca}$. Hence, from the above equation,

$$F_{ab} + F_{bc} = -F_{ca}$$
$$= F_{ac};$$

or, we get the same electro-motive force from a and c directly on contact as when we insert any other or, in fact, any number of other metals between them. This bearing of the conservation of energy on the question was not considered by Volta's followers, and so they were led into statements which caused Faraday to altogether deny the existence of contact electro-motive forces, and to refer the whole thing to the chemical actions.

The position assumed by the chemical theory, with which Faraday's name is associated, is this: (1) when two plates are placed in the liquid, but not in contact, they are brought to different potentials; (2) if they be then connected by a wire, electricity rushes along the wire to equalize the potential of the plates; (3) and since this difference of potential is constantly renewed, there will be a constant flow of electricity till the plate most acted on is consumed.

Those who maintain the chemical theory also do so now in a modified form. While maintaining that the chief seat of electro-motive force is the Zn-liquid junction, they admit a real, though they claim comparatively slight, potential difference at the metal contacts. The real existence of this potential difference at metal contacts has been shown by Thomson, and is evident from the facts of thermo-electricity.

The advocates of the contact theory do not attempt to explain the cause of the contact forces. The advocates of the chemical theory advance a reasonable explanation of the potential differences produced at the zinc-acid junction. It is this: The liquid in contact with the plates contains atoms, some charged positively, some negatively,—say, oxygen, every atom of which has a certain negative charge; and hydrogen, every atom of which has a positive charge. Both the Zn and the Cu plates attract oxygen, as is shown by their readiness to rust or oxidize. But the zinc attracts oxygen more strongly than does the copper. Now, in the liquid there are, at a certain moment, a goodly number of free atoms (§ 6), for some of the molecules are always breaking up and immediately recombining, with an interchange of atomic partners. The distance at which zinc will exert any appreciable attraction on an oxygen atom is very small,—say, one-ten-millionth of a millimetre,—and this is called the molecular range. The Zn plate, then, acts on all momentarily free atoms of oxygen within molecular range of it, attracting them to itself. But their place in the thin sheet of liquid near the plate, whose thickness is the molecular range, will then be immediately taken by other free atoms coming in by diffusion from more distant layers, and thus the

supply of oxygen atoms is kept up, and there will be a gradual procession of oxygen atoms through the liquid toward the zinc,—at a rate determined by the electro-motive force acting and the rate of diffusion natural to the liquid employed. Now, all the oxygen atoms that reach the zinc, each with its negative charge, neutralize a certain portion of the positive electricity of the zinc, and thus leave it charged negatively. If no channel be afforded for the escape of this negative charge, it soon becomes so large as to repel the similarly-charged oxygen atoms with as great a force as the zinc naturally attracts them, and then the process ceases.

44. Ohm's Law.—The basis of exact measurements in electricity is a famous law published by Dr. G. S. Ohm in 1827,—a law that has stood the test of numerous keen examinations since, and now deserves to rank with the laws of gravitation and of electro-static attractions and repulsions as a real law of nature.

Ohm's law is that the current produced in a conductor by an electro-motive force is proportional directly to the electro-motive force and inversely to the resistance of the conductor; or, C is proportional to E divided by R, which is written in mathematics thus :—

$$C \propto \frac{E}{R}$$

Such a proportion is equivalent to an equation into which a constant numerical factor (k) enters; thus,

$$C = k\frac{E}{R}$$

What this constant factor k is will depend on what units we employ. Now, by referring back to § 41, it will be seen that by our definition of the practical unit, R is unity when C and E are unity, or $1 = k\frac{1}{1}$; hence k is one and may be omitted; thus,

$$C = \frac{E}{R}$$

Our system of units was, in fact, chosen with a view to having this so.

46. Ohm's Law and Resistance.—The idea of electrical resistance is frictional opposition to the flow of electricity, just as ordinary friction between two bodies means opposition to the movement of one over the other. Now, we may write Ohm's law thus :—

$$R = \frac{E}{C}$$

So that resistance is the ratio of electro-motive force to current produced. The real meaning of Ohm's law is that this ratio is, for a given conductor in a given physical condition, a constant; so that our measure of the resistance of a conductor is the constant ratio of the electro-motive force producing a current in it to the current so produced.

The resistance of a conductor depends on the dimensions of the conductor, as follows: If the length of the conductor be l, the area of its cross-section a, then its resistance is

$$R = k\frac{l}{a},$$

where k is a constant independent of the dimensions of the wire. If we take a piece of the conductor of unit length and unit cross-section, $l = 1$ and $a = 1$, and then $R = k$; or, k is the resistance of a piece of the conductor of unit length and unit cross-sectional area, and is called the specific resistance of the substance of which the conductor consists.

Conductivity.—The conductivity, or conducting power of a conductor, will be greater, of course, the less its resistance. We may, then, take it as the reciprocal of the resistance, or $= \frac{1}{R}$, and then from Ohm's law it will mean the ratio of the current in the conductor to the electro-motive force that produces it.

46. Conditions on which Resistance Depends.—*The Material of the Conductor.*—Some substances are naturally good conductors, and

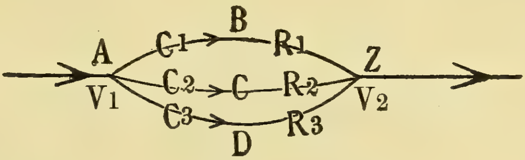


Fig. 16.

others naturally poor. Among metals, copper is one of the best conductors, and hence it is the most commonly employed. The conductivity of silver stands higher than that of copper, but its cost prevents its use. After copper come platinum, iron, lead, mercury, German silver, in the order named. It is interesting to note that this is also the order of the metals as regards conducting power for heat. In fact, the ratio of the conductivities for heat and electricity is nearly constant not only for metals, but also for alloys.

Physical State.—In all ordinary metal conductors the conductivity decreases as the *temperature* rises. The increase of specific resistance per unit rise of temperature is called the *temperature coefficient* of the substance. It is nearly the same for all pure metals except thallium and iron, being .0037647 per degree centigrade. Again, metals become worse conductors on having their *hardness* increased. The resistance of steel is increased by tempering, while hard-drawn copper wire is a worse conductor than annealed copper. Finally the resistance of a wire is changed by *strain;* stretching increases the resistance of the wire, while longitudinal compression decreases its resistance.

47. Conduction of Liquids.—Liquids are divided into two classes: (1) those which conduct without decomposition, as liquefied metals and

some compounds; (2) those which are decomposed by the passage of the current, and are called electrolytes, the process of their decomposition being called *electrolysis*. We shall take electrolysis up more fully a little later. But we anticipate enough to say that Ohm's law holds for electrolytes also (§ 62).

48. Resistance of a Multiple Arc.—A multiple arc is the technical name applied to an arrangement of wires in which several wires connect two points so that several channels are open to the flow of electricity. (Fig. 16.) We are supposed to know the separate resistances,—say, R_1, R_2, R_3,—and we wish to know what the effective resistance of the combination will be. If the potential at A and Z be V_1 and V_2, then the difference, $V_1 - V_2$, will be the electro-motive force, E, acting along each wire; and then, by Ohm's law,

$$C_1 = \frac{E}{R_1}, \; C_2 = \frac{E}{R_2}, \text{ and } C_3 = \frac{E}{R_3}$$

Suppose these wires removed and replaced by a single wire of resistance, R, such that the current still remains the same, or $C = C_1 + C_2 + C_3$; then, since Ohm's law would still hold for this conductor,

$$C = \frac{E}{R}$$

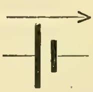
$$\text{Hence, } \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

This means that the conductivity of the combination (or the *reduced* conductivity of the multiple arc) is simply the sum of the conductivities of the separate conductors, and R can be readily calculated.

As a simple example, let us find the resistance of a wire that would just replace three in multiple arc, whose resistances are 1, 2, and 3 ohms, respectively:—

$$\frac{1}{R} = \frac{1}{1} + \frac{1}{2} + \frac{1}{3} = \frac{6+3+2}{6} = \frac{11}{6} \therefore R = \frac{6}{11} \text{ ohm.}$$

49. Arrangement of a Number of Cells for Greatest Current.— For the purpose of what follows, we shall employ the simple conventional sign,



to represent a cell, the large line representing the zinc, or positive plate, and the small one the copper, or negative plate, so that the current flows in the direction of the arrow. We must also define the terms *external* and *internal resistance*. That part of the resistance of a circuit which is constituted by the cells used is called the internal resistance, and the remainder, due to the parts of the circuit outside the cells, is called the external resistance.

There are two separate ways in which we can arrange a battery of cells, and a third way that is a combination of the two.

(*a*) *In series*, *i.e.*, the copper of each being connected to the zinc of the next, thus :—

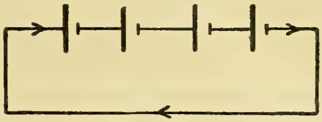


FIG. 17.

(*b*) *Abreast* or in multiple, *i.e.*, all the coppers being joined together and all the zincs together, thus :—

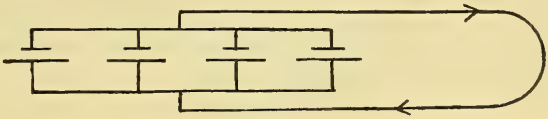


FIG. 18.

Comparison of the Two.—Let the electro-motive force of each cell be E. Then it is easily seen that in the arrangement in series the second zinc plate is at the same potential as the first copper plate, and therefore E in potential below the first zinc plate. The second copper plate is, therefore, 2E below the first zinc plate. The last copper plate is nE in potential below the first zinc plate; hence the electro-motive force of the combination is nE. But if the resistance of each cell be R, then the resistance of the combination is nR. If, then, the internal resistance be much larger than the external, the whole resistance of the circuit will be n times what it would have been with only a single cell, while the electro-motive force will have been increased n times also; so that the n cells will not give a much better current than one cell.

If, on the other hand, the external resistance be very large compared with that of a single cell, the arrangement in series will be advantageous, since it greatly increases the electro-motive force in the circuit without adding appreciably to the total resistance.

Turning now to the arrangement abreast,—since all the positive plates are at the same potential and all the negative plates at the same potential, the electro-motive force of the whole arrangement is simply that of a single cell. But since n channels are now afforded for the flow of the current through the battery part of the circuit, the resistance of the combination will only be one nth that of a single cell, or R/n. If, now, R be small compared with the external resistance, we shall not have reduced the whole resistance of the circuit much by dividing R by n, and so the arrangement will hardly be more effective than a single cell would be. But if the internal be the chief portion of the resistance, then by dividing it by n we shall have greatly reduced the total resistance.

Hence, a general rule: If the resistance of a single cell is less than the external resistance, arrange your cells in series; if greater, arrange your cells abreast.

(*c*) But there is a third way of arranging the cells. Suppose, *e.g.*, we have 24 cells, then we can divide them into six groups of four each. Each group of four we can arrange in series so as to act as a single cell, of an electro-motive force 4E and an internal resistance 4R. Then these six groups can be arranged abreast, so that the electro-motive force is still 4E, but the internal resistance of the combination $\frac{4R}{6}$; and then, if the external resistance be r, by Ohm's law we shall have a current of

$$\frac{4E}{r + \frac{4R}{6}} = \frac{24E}{6r + 4R}$$

But we could also have divided this into eight groups of three cells each, and then the current would have been

$$\frac{3E}{r + \frac{3R}{8}} = \frac{24E}{8r + 3R}$$

or four groups of six each, and which of these will give the greatest current will again depend on the relative magnitude of r and R; and if the matter is investigated mathematically, we shall arrive at the following rule for the arrangement giving greatest current: Divide the cells into a number of groups, such that the ratio of the number of groups to the number in each group shall be as nearly as possible equal to the ratio of the resistance of a single cell to the total external resistance. Then arrange each group in series (*a*), and put all the groups abreast (*b*).

Wheatstone's Bridge Measurement.

50. Standards of Resistance and Electro-motive Force.—We proceed now to indicate briefly the exact methods employed in measuring resistance and electro-motive force. Before doing so, we must describe the standards used in measuring resistance.

Resistance.—At a given temperature a given wire has a perfectly definite electrical resistance. Accordingly, if we take a bobbin of wire (German silver is usually employed), the coils being covered with silk or some insulator, so that there is no "short-circuiting," or passage of current from coil to coil in contact (the current must pass longitudinally from end to end of the wire), we can use such a bobbin as a standard for comparing electrical resistance; and further, if we take a series of such, graduated to ohms and parts of an ohm, in the same way as weights for a fine balance are graduated in grammes and parts of a gramme, such a series of graduated resistances will enable us by comparison to measure any unknown resistance. Such a series, arranged with their terminals

on the cover of a box, in which the bobbins hang for protection, is called a resistance-box. The alloy German silver, which consists of nickel and copper, is usually employed, because it has a low temperature coefficient, *i.e.*, suffers but small proportionate increase of resistance on increase of temperature.

Electro-motive Force.—Any very constant cell can be employed for comparing electro-motive forces. The one usually employed is a cell invented by Latimer Clark, and having a very constant electro-motive force. The poles are amalgamated zinc and mercury, and the liquids are sulphate of zinc and a paste of sulphate of mercury. Its electro-motive force is 1.457 V.

51. WHEATSTONE'S BRIDGE.—Take a multiple arc of two branches, A C B and A D B, and pass a current from a battery through it. The potential at A is the same for both branches, also the potential at B. It falls off

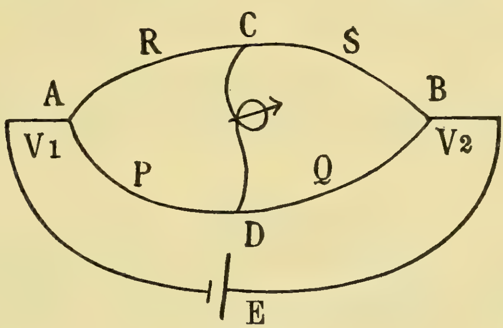


FIG. 19.

along A C B, and also along A D B. Now by Ohm's law, since the current in all parts of A C B is the same, the fall of potential in any part of A C B is proportional to the resistance of that part. Hence, if we take two points, C and D, at the same potential, then C must divide the resistance of A C B in the same proportion as D divides that of A D B. Calling the resistances of the parts P Q and R S, we have

$$\frac{R}{S} = \frac{P}{Q} \text{ and } R = \frac{P}{Q} S;$$

and since C and D are at the same potential, if we join them by a galvanometer it will indicate no current. Hence, if we adjust the resistances till there is no current given by the galvanometer, and let P, Q, and S be known resistances given by a resistance box, we have R, which we suppose to be an unknown resistance, to be measured. This method of arranging so that the galvanometer shows no current, and thus deducing the unknown quantity, is called a *null* method. It is the ordinary way of measuring electrical resistances.

When in any such net-work two branches are so related (as the

battery and galvanometer branches are in this net-work) that a change in one (such as suddenly "throwing in" the battery) does not affect the current in the other, they are said to be conjugate branches.

Galvanometer Resistance.—If we wish to know the resistance of a galvanometer we may simply put it in the unknown arm, R, in which case we shall have to employ a second galvanometer, C D. But this second galvanometer in C D is unnecessary, for all we need to see is that no current flows through C D,—*i.e.*, no change in the existing currents is caused by connecting C and D, and this can be equally well seen by watching the galvanometer in A C while we make and break, by means of a key, the continuity of the simple wire joining C and D. This is Thomson's method of finding a galvanometer resistance.

Battery Resistance.—Again, to find the resistance of a battery, we may put it in A C and proceed as at first, with a galvanometer in C D and battery in A E B. But, now, the battery in A E B is unnecessary, for the battery introduced in A C keeps up currents in the net-work and the battery in A E B can be simply replaced by a key; and if we adjust the resistances in the arms P, Q, and S till no effect on the galvanometer in C D is produced by making and breaking with the key in A E B, then, as before, we have

$$R = \frac{P}{Q} S.$$

General Rule for Battery or Galvanometer Resistance.—Starting with the original arrangement, to modify it, in order to find the resistance of a galvanometer or battery, all we have to do is to put the battery or galvanometer in the unknown arm, R, and replace the battery or galvanometer of the net-work by a key, and then seek a *null* adjustment, whereupon we have

$$R = \frac{P}{Q} S.$$

52. Comparison of Electro-motive Forces.—The method we shall employ is what is known as du Bois-Reymond's compensation method: Let e be the electro-motive force of a battery to be measured, and E that

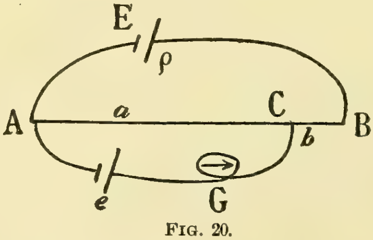


Fig. 20.

of a standard cell of known resistance, ρ. Join the poles of E by a long, thin wire lying beside a graduated scale, by means of which we can read

the lengths of parts of the wire. Also, join e in series with a galvanometer to A and a variable point, C, in A B. E will tend to produce a current in A G C in the direction from A to C through G. On the other hand, e will tend to produce a current in the opposite direction. Now, by adjusting C along A B so as to increase or decrease the resistance, a, of A C, we can send more or less of the current from E through A G C, and so can adjust till the currents produced by E and e in A G C just neutralize one another, which will be indicated by the galvanometer, G, showing no deflection.

The reason no current goes through G is that, although the battery E produces a slope of potential along A G C, the battery e produces an equal and opposite one. The slope produced by E, or the difference of potential between A and C, is the same part of the whole electro-motive force of E that the resistance of A C—*i.e.*, a—is of the whole resistance of the circuit E A C B, *i.e.*, $\rho + a + b$. Putting these two statements together, we see that

$$e : E :: a : \rho + a + b.$$

Now, a, ρ, and b are all known or measurable resistances; hence the ratio e/E can be found.

Electrical Energy and Chemical Energy; Electrolysis.

53. Conduction in Liquids.—Unlike as electrical energy and chemical energy may be at first sight, still, they are both forms of energy, and, therefore, capalbe of being changed into each other. Chemical energy we know consists in the energy of certain attractions and repulsions. Electrical energy consists in the energy of something in motion. The currents we have been treating of so far were examples of the change of chemical energy in Volta's cell into energy of a current of electricity. We proceed now to consider the converse process,—the change of the energy of an electrical current into chemical energy. The chief example is what occurs in the passage of electricity through liquids.

As regards the conduction of electricity, liquids may be divided into three classes:—

(1) *Those that Conduct Like Solids.*—This class contains all metals in the liquid state, whether like mercury at ordinary temperatures or like iron fused at a high temperature.

(2) *Those that Do Not Conduct at all.*—To this class belong pure water, pure hydrochloric acid, and generally all pure liquefied hydrogen acids (except HCN), fluid chlorine, bromine and iodine, oils and resins (gases and vapors are also non-conductors; any decomposition in them is due to convective discharge).

(3) *Those that Conduct, but with Chemical Decomposition.*—To this class belong dilute acids and most simple binary compounds, *i.e.*, compounds of two elements and compounds derived from them by double decompositions.

54. Typical Case of Conduction with Decomposition.—The meaning of electrolysis has already been explained. By derivation, it means the electrical decomposition of chemical compounds. Faraday was the

inventor of this and most of the following terms. A compound so decomposed is called an *electrolyte.*

To explain the terminology, we shall take a typical case. In a vessel containing zinc chloride ($ZnCl_2$) suspend two platinum strips connected with a battery. It will be found that zinc appears at one strip and chlorine at the other. These strips are called electrodes, and the cell so equipped is called a voltameter. The zinc is precipitated, and the chlorine forms platinic chloride with the platinum. The decomposing current enters at the strip connected with the copper or negative plate of the battery, and this strip is called the *anode.* The current leaves at the strip connected with the zinc or positive plate of the battery, and this strip is called the *cathode.* These terms are taken from the analogy of the motion of the sun, the anode being the place where the current "rises" (*ana hodos*, or way up), and the cathode where it sets (*kata hodos*, way down).

Thus it will be seen that the zinc travels with the current to the cathode, and the chlorine against the current to the anode. These components are accordingly called *ions*, from a Greek root meaning to go: the ion that appears at the anode being called the *anion*, and that which appears at the cathode the *cation.*

The positive current goes from the zinc to the copper and carries zinc with it; hence, the zinc, or cation generally, is called electro-positive. The negative current goes from the copper to the zinc and carries chlorine with it; hence, the chlorine, or anion generally, is called electro-negative.

Any reactions—following ordinary chemical laws—between the primary products of electrolytic decomposition, the electrolyte, and the electrodes are called *secondary reactions.*

55. Comparison of Simple Conductors and Electrolytes.—*Contrast of Resistance.*—The resistances of electrolytic conductors are very high compared with those of simple metallic conductors,—*e.g.*, pure H_2SO_4 has seventy million times as great a specific resistance as pure copper.

Contrast of Temperature Effects.—The resistance of metals is increased by rise of temperature,—of pure copper about $\frac{3}{8}$ per cent. per degree centigrade. The resistance of electrolytes is decreased by rise of temperature,—of pure H_2SO_4 about 4 per cent. per degree centigrade.

Faraday's Law of Conductors.—Faraday established a law, to which there seems to be *no* exception, viz., that all substances which in the solid state are very bad conductors, but conduct on being melted, are electrolytes, *i.e.*, conduct with decomposition.

56. Faraday's Law of Electrolysis.—Faraday discovered that the resistance to the separation of an element from a compound by an electric current is the same, no matter what the compound, and depends merely on the element. Hence the law of electrolysis: The amount of ion that appears at an electrode in a second is equal to the strength of the

current (supposed constant during a second) multiplied by a constant called the *electro-chemical equivalent* of the ion. For example, if the electro-magnetic unit of an electrical current (the ampère) flow per unit of time (a second), it will liberate .000010352 gramme of hydrogen, which therefore is the electro-chemical equivalent of hydrogen. We can readily make out a relation between electro-chemical and chemical equivalents; for if, in the above case, a certain quantity of H is liberated at the cathode, the quantity of Cl combined with it (supposing the electrolyte to be HCl) must appear at the anode. Now, every atom of H has combined with it one atom of Cl. Hence the quantity of Cl liberated must have weighed more than that of H in the proportion of the atomic weight of Cl to that of H, *i.e.*, in the ratio of 35.5 to 1. Again, in the above typical case, the electrolysis of $ZnCl_2$, since in each molecule there are two atoms of Cl to one of Zn (*i.e.*, one of Zn is chemically equivalent to two of Cl; or, the "valency" of Zn is 2), only half as many atoms of Zn will be set free by electrolysis as of Cl; and since the atomic weights are of Zn 65 and of Cl 35.5, the weights liberated will be as $\frac{65}{2}$ to 35.5. Hence the electro-chemical equivalents of substances are proportional to their atomic weights divided by their "valencies."

57. POLARIZATION AND TRANSITION RESISTANCE.—The decomposition of the electrolyte, with the consequent deposition of the products of decomposition on the electrodes, produces two effects.

Polarization.—In the first place, the change in the nature of the surfaces produced by the deposition means an alteration in the nature of the contacts, and, therefore, a change in the electro-motive force of the circuit. This will be true whether the products of decomposition are simply deposited on the plates or combine with them chemically. The new electro-motive force thus introduced is usually opposed to the main electro-motive force, and is, consequently, called a "back" electro-motive force, or electro-motive force of polarization. Its presence is shown by suddenly throwing the voltameter out of the main circuit and connecting it with a galvanometer. It will then be found to act as a cell itself, though its electro-motive force will, as a usual thing, very rapidly fall away. The "back" electro-motive force is caused by the tendency of the dissociated atoms to re-unite, and thus is a measure of the attraction of these atoms, or of their "chemical affinity."

Minimum Electro-motive Force Required for Electrolysis.—It is evident that the initial electro-motive force required to start electrolysis must exceed the "back" electro-motive force that would be produced by the process. Hence we have usually a lower limit to the electro-motive force that will start electrolysis. For instance, a single Smee's cell, no matter how large and close together its plates, will not electrolyze acidulated water, for the back electro-motive force so produced is 1.47 V, which is greater than the electro-motive force of a Smee cell. The current will cease before it has produced any appreciable effects.

58. SECONDARY ACTIONS.—These may be classified as follows:—

(*1*) *Appearance of Ions in Abnormal Molecular States.*—The most important example of this is the production of ozone along with oxygen in the water voltameter. The amount produced is never large, but can be readily recognized in the ordinary way by making it replace the iodine in potassium iodide, setting free the iodine to act on starch. The amount produced is largest when chromic and permanganic acids are electrolyzed.

(*2*) *Resolution of Compound Ions.*—As an example, take the electrolysis of oxyacids, *e.g.*, H_2SO_4. Here the ions are H and SO_4. The latter, which has been named Oxysulphion, immediately breaks up into O and SO_3.

(*3*) *Reaction of Ions on Electrodes.*—At the cathode, where the metals are set free, the usual result is the formation of an alloy of the metal of the cathode and the metallic ion. An example can be readily obtained by electrolyzing copper sulphate with platinum electrodes. At the cathode an alloy of copper and platinum is formed which penetrates a considerable distance into the platinum. This union of the ions with the electrodes takes place the more readily because the ions are in the *nascent* state (§ 4). The oxygen liberated at the anode frequently unites with the anode, even carbon becoming then oxidized to CO and CO_2.

(*4*) *Reaction of Ions on Fluids at Electrodes.*—Such nearly always occurs unless the ions act on the electrodes themselves. Take, as an example, the electrolysis of sodic sulphate or Glauber's salts,—Na_2SO_4. The immediate effect of electrolysis is to break it up, thus:—

$$Na_2SO_4 = Na_2 + SO_4.$$

The Na_2 appears at the cathode and reacts on the water there, thus:—

$$Na_2 + 2H_2O = 2NaHO + H_2.$$

The SO_4 breaks up into O and SO_3. The former appears at the anode and the latter unites with water, thus:—

$$SO_3 + H_2O = H_2SO_4.$$

The presence of the H_2SO_4 and NaHO can be readily indicated by mixing some extract of red cabbage with the solution. If necessary, a drop or two of acid is added till the whole is a dull-purple color. Then the presence of the acid at the anode is indicated by its turning the solution red, and that of the alkali at the cathode by its turning the solution green.

59. THE ELECTRO-CHEMICAL SERIES.—The preceding may have suggested that an element was always an anion or always a cation; but this is not so. The terms anion and cation are merely relative. It is found that all substances can be arranged in a series, such that any substance is a cation when combined with any lower in the series and an anion to any higher; the beginning of the list being accordingly most electro-positive

and the end most electro-negative. At the head of the list, or most strongly electro-positive, stand K, Na, Li, Ba, etc.; at the end I, Br, Cl, Fl, N, Se, S, O (for full list see *Encyclopædia Britannica*, "Electrolysis"). Thus the same substance may be sometimes an anion and sometimes a cation, according to the position of its companion ion in the list.

60. Electric Osmosis, or Cataphoresis.—In ordinary osmosis (§ 6) the liquids must be different. But even with the same liquid on both sides of the porous partition the passage of an electric current from one side to another will cause more liquid to diffuse in one direction than the other, so that it will rise to a greater height on one side than on the other. This is called electric osmosis, or cataphoresis. The latter name is derived from the fact that the liquid is carried down (*cata*, down; *pherein*, to bear) with the current, *i.e.*, more liquid passes by diffusion through the partition in the direction of the current than in the opposite direction. The process may be shown by using a weak solution of starch and a weak solution of iodine separated by a porous partition. The current, on passing from the iodine to the starch, will carry some of the former with it, thus coloring the starch by chemical reaction with the iodine. This

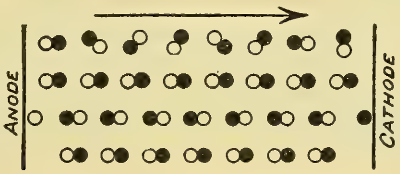


Fig. 21.

● an atom of hydrogen; ○ an atom of chlorine; ——> direction of current.

process plays an important part in medical applications of the electric current, or the process known as *cataphoric medication*.

61. The Mechanism of Electrolysis—Grotthüss and Clausius.—This process of electrolytic conduction is at first sight somewhat paradoxical. For, though the current passes from electrode to electrode, and must, therefore, pass through the liquid, yet the chemical evidence of the current, viz., decomposition, only appears at the electrode. Does, then, the current produce no decomposition in the body of the liquid?

Grotthüss's Theory.—The answer given by Grotthüss is that there is decomposition everywhere, but, whereas there is immediate recomposition in the body of the liquid, there is no such recomposition at the electrode, and so the components appear there. This theory may be represented thus (Fig. 21): In the electrolysis of HCl the first thing that happens is a wheeling of all the molecules into line, all the H atoms pointing toward the cathode and all the Cl atoms toward the anode. Then each molecule ruptures and each atom turns to the dissimilar atom on the other side and combines with it, forming new molecules, but leaving free atoms of Cl at the anode and free atoms of H at the cathode. Again the

molecules wheel around into position and again the process is repeated, and so on.

This theory will evidently explain (1) the appearance of the products of decomposition at the electrodes and (2) Faraday's law as regards a single electrolyte. It does not, however, explain (3) the transference of the electricity nor (4) why the same amount of an ion should be separated from different electrolytes by the same current.

Berzelius's Extension of the Theory.—The extension made by Berzelius is that on the union of H and Cl to form HCl electrical distribution takes place in a similar way to that of magnetism in a bar magnet, H becoming the positive and Cl the negative pole. When the anode has become sufficiently highly charged with positive electricity its attraction on Cl becomes greater than that of the H atom, and so the HCl molecule is decomposed. Helmholtz further suggested that each atom carries with it a certain definite charge. If the atoms on decomposition cling to their electrical charges these latter cannot be passed around to the other plate, and may accumulate and partly neutralize the attraction of that plate for the ions. This gives rise to an electro-motive force of polarization.

62. Electrolytic Resistance and Ohm's Law.—The measurement of the resistance of an electrolyte is a matter of considerable difficulty, chiefly owing to the complications introduced by the polarization electromotive force, which, so far as weakening the current is concerned, is equivalent to an added resistance. The means resorted to have been these:—

(1) Horsford used a voltameter in which the electrodes were at measurable distances, which could be altered. The plates were brought nearer together by a known amount, and the current kept constant by inserting a known resistance from a resistance-box. The current being constant, it was assumed the polarization was, and so the added resistance was the resistance of a thickness of the electrolyte equal to the distance by which the plates were brought nearer.

(2) Beetz employed the principle that carefully amalgamated zinc plates in a neutral solution of zinc sulphate are not polarizable, and so measured the resistance of zinc sulphate.

(3) Paalzow inclosed the electrolyte in a siphon which dipped into vessels of porous earthenware filled with the electrolyte. Those porous vessels were immersed in beakers filled with zinc sulphate, at the bottoms of which were large amalgamated zinc discs forming the electrodes. Thus there would be no polarization except possibly at the surface of contact of the liquids, and that would be small.

(4) Kohlrousch and Nippoldt used rapidly alternating currents, and so the ions would recombine as fast as separated and no polarization would ensue.

By all these means Ohm's law has been fully proven to hold true for liquids as well as for solids.

63. Secondary or Storage Cells.—We have seen that, in general, the passage of a current through a voltameter alters the electrodes by secondary actions between the ions and the electrodes. Thus, if before the passage of a current the electrodes were quite similar in substance, after the passage they are dissimilar; and therefore the voltameter has become

a voltaic cell and can be detached and used as such until, by the reverse current started, the work done on the electrodes by the original current is undone, or the electrodes are discharged. A cell so constructed is called a secondary cell, because it is not of itself primarily a generator of a current, but only subsequent to the passage of a current through it. Secondary cells are also called storage cells, but it is not meant thereby that they store up electricity. What is meant is that they store up energy, namely, in the chemical form, and that this energy can be reproduced as the energy of an electric current. They are also frequently called accumulators. Any voltameter in which similar electrodes are rendered dissimilar by the passage of a current becomes a secondary cell, but only a few have been so constructed as to maintain a current for any considerable length of time.

Grove's Gas-Battery.—If acidulated water be electrolyzed in a closed voltameter with long electrodes of platinum, so that the gases are retained surrounding the electrodes, after the decomposition has proceeded for some time the voltameter has become a charged secondary cell, and can

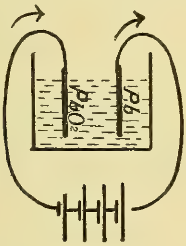


FIG. 22.

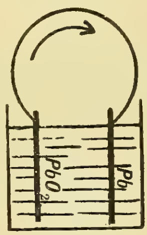


FIG. 23.

be used as such until all the decomposed gases have disappeared by decomposition. Or the gases may be otherwise prepared and then introduced.

Planté's Secondary Cell.—In Planté's secondary cell the electrodes are lead plates immersed in dilute H_2SO_4. In its original form the preparation of the plates, or the "formation" of the cell, as it was called, was a troublesome process. First, a current was passed through it till the surface of the anode was oxidized into PbO_2 (Fig. 22). Then the current was reversed, whereupon the PbO_2 was reduced, leaving that surface covered with "spongy" lead, and covering the surface of the other plate with PbO_2. The current was again reversed, and so on for weeks, until the lead surfaces had been acted on and rendered "spongy" to some depth. The plate that last served as anode remained deeply coated with PbO_2.

If the cell be now used to generate a current, this current will be in the direction from the peroxidized plate to the plain lead plate (Fig. 23). The chemical changes will consist in the reduction of the PbO_2 to PbO, and the oxidation of the Pb plate to PbO; so that the two plates become

similar. When this state is attained the cell is "run down." It must then be "re-charged," which consists in sending a reverse current so as to again peroxidize one plate and reduce the other to spongy lead, and thus the cell is again charged. (In this simple account we have neglected the presence and action of $PbSO_4$ on the plate. Chemically it is negligible, but mechanically it seems to serve the important purpose of separating the PbO_2 from the Pb below it, and so preventing the PbO_2 from being reduced by mere "local action" between the PbO_2 and the plate on which it is, and thus giving no current.)

Fauré's Modification of Planté's Cell.—There is a great waste of energy in the process of "formation" of Planté's cell. To avoid this, Fauré coated the plate to begin with with minium, or red lead,—Pb_2O_3, or $PbO.PbO_2$. Then, on charging by passing a current we get H_2 set free at the cathode and O at the anode, and the reactions that take place are :—

$$\text{At cathode, } Pb_2O_3 + 3H_2 = 3H_2O + \underline{2Pb}.$$

$$\text{At anode, } 3Pb_2O_3 + 3O = \underline{6PbO_2}.$$

Thus we shall have one plate peroxidized and the other spongy lead, and the cell is charged ready for use.

The chief difficulty in this cell is to make the minium adhere to the plates. For this purpose the plates are gridironed and the minium packed in the interstices in the lead, or some other similar device is resorted to.

The electro-motive force of such a cell is over two volts; so that to charge a single cell with primary batteries at least three Bunsen cells are required. If all the storage batteries during charging are connected abreast, any number can be charged by a few Bunsen elements (requiring, of course, proportionately longer time), and then they can be connected in series, and so a much higher electro-motive force obtained than from the charging battery.

Electrical Energy and Heat Energy.

64. Their Interchangeability.—Heat, being a form of energy, is interchangeable with other forms of energy, and among them with electrical energy. Of the change of electrical energy into heat energy we have an example in every current of electricity. For heat is the form of energy generated whenever work is done against frictional resistance; and as electrical resistance is of the nature of friction, and all conductors offer some resistance to electric currents, heat is generated by every current. We shall first discuss the change of electrical energy into heat energy, and then the change of heat energy into electrical energy. The currents obtained by this latter process are usually called thermo-electric currents.

65. Development of Heat in a Circuit.—A current of electricity generated by a voltaic cell is capable of doing work, such as turning an electric motor. But if the current be merely passed through a wire doing no work, it must produce heat, since the same amount of chemical energy is used up in the cell, and it must be reproduced in some other form of energy.

It can be shown without difficulty that the heat so produced in a wire varies as the square of the current and the first-power of the resistance conjointly. For by definition the difference of potential between the ends is the work done in carrying a unit of positive electricity from one end to the other. Hence, if the difference of potential or electro-motive force be E and the current be C, then, since C is the number of units of electricity that pass in unit time, the work done in unit time is $W = EC$; and by Ohm's law $C = \frac{E}{R}$, or $E = CR$; hence, $W = C^2R$. If C and R be in C. G. S. units, W will be the number of units of heat energy produced per second.

Thus the heat energy produced depends only on the current and resistance. Hence, to avoid loss of energy by heating the conductors, a small current and low resistance is to be used. This is the secret of electrical transmission of power. The power is transmitted as an electrical current of small current-strength, though high electro-motive force, and then when it is to be used it is transformed into a larger current of lower electro-motive force.

Where heat is to be developed high resistance is used. In electro-cautery the surgeon wishes to burn off a growth by a heated wire, and so he uses not silver, which, for one thing, would have too small a resistance, but platinum, which has a higher resistance.

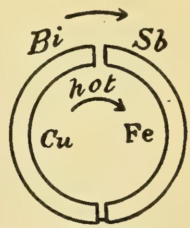


Fig. 24.

Again, incandescent lighting depends on the heating to incandescence of a carbon filament of high resistance. In the arc-lamp the resistance is in the carbon vapor between the carbon points, and the light is produced by this incandescent vapor, but chiefly by the heated ends of the carbon rods.

66. Production of Electricity from Heat.—We now proceed to the converse process,—the transformation of thermal energy directly into electrical energy. The first to discover the possibility of this was Seebeck. He found that in a circuit of only two metals a current can be produced by simply heating one junction to a higher temperature than the other. This can be very readily shown by winding the ends of a copper and an iron wire together and then heating that junction, while the other ends are connected to a galvanometer. A current will be found to flow in the direction from copper to iron through the hot junction. The same thing can be shown still more strikingly by using bismuth and antimony, when the current will be found to flow from

bismuth to antimony through the hot junction. Similar phenomena will be produced by using any pair of metals.

Thermo-Electric Power.—To render our ideas more definite, in describing the current or electro-motive force produced by any such couple of metals, we must specify the difference of the temperatures at which the junctions are. Moreover, the electro-motive force may depend not only on the *difference* of temperature of the junctions, but also on their actual temperatures. Hence, we define the *thermo-electric power* of a couple at a specified temperature as the electro-motive force produced by keeping one junction $\frac{1}{2}°$ C. above and the other $\frac{1}{2}°$ C. below that temperature. With this definition it will be found that the thermo-electric power is different at different temperatures (§ 69).

67. Thermopiles and Thermo-Electric Batteries.—With a thermo-electric couple, then, we have a means of generating electric current directly from heat. But the electro-motive force of such a current is very low,—for a Cu-Fe couple with one junction 1° C. above the rest of the circuit it is only .0000137 volts, and for a Bi-Sb couple it is .000117 volts.

But we can obtain a much greater electro-motive force in the following way: Instead of taking a single piece of Bi and a single piece

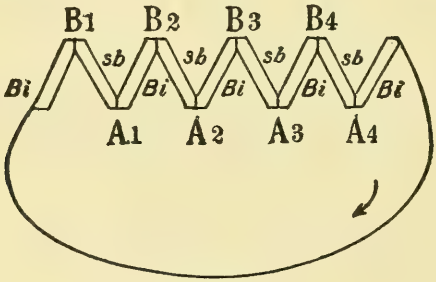


Fig. 25.

of Sb, take a number of pieces and connect them up alternately as in the diagram. Then, if a B junction be heated, it is evident, by the rule above, the current will be in the direction of the arrow; but if any A junction were heated, the current would be in the opposite direction. Hence, to get a greatly-increased electro-motive force, we heat all the B junctions, keeping all the A junctions at the ordinary temperature. Thus, by multiplying the number of junctions, we can multiply the thermo-electro-motive force to any desired extent.

Such thermo-electric multipliers have been made for different purposes in two different forms. One form—the *thermopile*—is used as a very sensitive detector of heat. It consists of a circuit such as described, except that the strips are packed together, with strips of paper or gutta-percha between them for insulation, into a box, so that all the A junc-

tions are exposed at one end and all the B junctions at the other. When either end is exposed to a source of heat, a current will be indicated by a sensitive galvanometer in circuit with the thermopile.

The Thermo-Electric Battery.—The above arrangement can also be employed to generate currents. For this purpose the cold junctions must be kept at a low temperature,—*e.g.*, by immersion in ice; and the hot junctions heated to a high temperature,—*e.g.*, by immersion in boiling water, or by heating by gas-burners or some similar means. Such batteries have been made by Pouillet, Becquerel, Clamond, and others, and can be used for such purposes, as electro-cautery and telegraphy, as do not need a very considerable electro-motive force, but only a large current.

68. Heating or Cooling of Junction by Passage of Current.—We have seen that in any part of a conductor heat is generated by the passage of a current. Such heat is due simply to the frictional resistance the conductor offers to the passage of a current. We have also seen that, conversely, if one junction of a circuit of two different metals be heated, a current is produced by the absorption of heat. But the former is not quite the converse of the latter. The proper converse of this would be if heat could be produced at the junction by the passage of a current. This can really be done, as was discovered by Peltier. His discovery was this: Pass a current through a junction of two different metals; then heat will be disengaged if the current be in opposition to the direction in which a current would be produced by heating the junction, and heat will be absorbed if the current be in the direction of the current that would be produced by heating the junction.

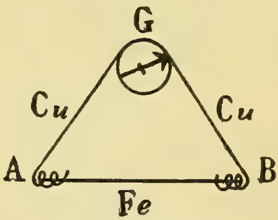


Fig. 26.

For example, if a current be passed through a Bi-Sb junction from Sb to Bi, the junction will be heated by disengagement of heat; if the current be passed in the opposite direction, from Bi to Sb, the junction will be cooled by absorption of heat.

There will be no difficulty in remembering these facts if it be remembered that, both in the Seebeck effect and in the Peltier effect, a current from Bi to Sb is always attended with absorption of heat.

69. Neutral Point and Reversal.—If we connect two Cu wires to a galvanometer and also wind their free ends around an iron wire, A B (Fig. 26), we can verify the following phenomena discovered by Cumming. Heating the junction, B, a current will go in the direction $\overrightarrow{\text{B A}}$, as shown by the galvanometer. It will increase heat at a decreasing rate: when B is at 260° C. it will become steady, and then will decrease until at 500° C. (supposing A to be constant at 20° C.) it will become zero, and then will turn in the opposite direction.

Now, it will be noticed that the temperature of reversal is as much above 260° C. as the temperature of A is below it. This would be true no matter what the temperature of A. Thus,

A being at	20°	(= 260 — 240°),	reversal occurs at	500°	(= 260 + 240°).
" "	" 100°	(= 260 — 160°),	" "	" 420°	(= 260 + 160°).
" "	" 250°	(= 260 — 10°),	" "	" 270°	(= 260 + 10°).
" "	" 259½°	(= 260 — ½°),	" "	" 260½°	(= 260 + ½°).

Now, by remembering the definition of thermo-electric power at a certain temperature as the electro-motive force when one junction is half a degree above and the other half a degree below that temperature, the last result in the table is readily interpreted as meaning that at 260 degrees the thermo-electric power of a Cu-Fe couple is zero, or the metals are *neutral* to one another. Hence, 260 degrees is called the *neutral point* for an Fe-Cu couple.

Similar results hold true for all other couples. Each couple has its neutral point or point of zero thermo-electric power, and when one junction is a certain number of degrees below the neutral point reversal will occur when the other is an equal number of degrees above it.

70. Thomson Effect.—From the above results Sir William Thomson reasoned as follows : When one junction is kept at the neutral temperature and the other at a lower temperature, there is undoubtedly a current, viz., from Cu to Fe through the hotter junction. Now, since in a junction at the neutral temperature the metals are neutral to each other,—*i.e.*, show no difference of electro-motive force,—the Peltier effect is also at that temperature zero, *i.e.*, no heat would be absorbed or disengaged by passing a current through a junction at that temperature. Hence, there is no heat absorbed at the hot junction. Again, there is not only no heat absorbed but even heat given out at the cold junction. Whence, then, the energy of the current? It must be that heat is taken in along the wires themselves. Now, undoubtedly heat is not taken in when a current passes along a wire all parts of which are at the same temperature ; so that the absorption of heat along the wires must be in consequence of their slope of temperature from their hot to their cold ends.

So Thomson was led to the very important conclusion that metal conductors can be divided into two classes. If a conductor belong to the first class a current passing from hot to cold parts along it will absorb heat. Iron belongs to this first class. If the conductor be of metal belonging to the other class, a current on passing from hot to cold will tend to disengage heat. Cu belongs to this second class.

Thus, in Cu the current tends to warm the colder parts and thus equalize the temperature throughout, just as a current of water passing from a hot part of a pipe to a cold part would, and in iron the reverse happens. Using this analogy the whole thing is conclusively summed up in the statement that in Cu electricity has a *positive specific heat* (*i.e.*, gives out heat on cooling), while in Fe it has a *negative specific heat* (*i.e.*, takes in heat on cooling).

Radiant Electrical Energy.

71. Magnetic Field of Current.—We have already (§ 38) touched on the effects produced by a current beyond the conductors themselves in which it flows. We shall now take up briefly this radiation of energy by the electric current. For fuller details of parts bearing direcely on medical applications the reader is referred to the section on faradic current.

The facts on which we founded the statement that the current had a magnetic field were these :—

(1) *Magnet Moved by Current.*—A current in a conductor will deflect a freely-suspended magnet-needle near it.

(2) *Magnet Produced by Current.*—A spiral current will make a magnet of a core of iron inclosed in the spiral.

We shall first take up the converses of these.

72. Momentary Current Produced by Motion of Magnet.—The converse of (1) above would be the generation of a current by the movement of a magnet. This can be shown by inserting a bar magnet into a coil of wire in circuit with a galvanometer and then withdrawing it. It will be found that both at insertion and withdrawal a *momentary* current flashes through the coil, and the directions of these currents are determined as follows: If the bar were not already a magnet, to make it into a magnet with its poles in the direction of the actual magnet would require a current in a definite direction in the coil. Let us call the current that would thus produce the magnet a direct current, and one in the opposite direction a reverse current.

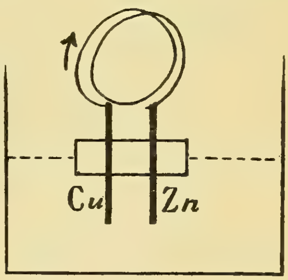


Fig. 27.

Then we may state the above result as follows: The insertion of a magnet into a coil starts a reverse current, and its withdrawal a direct current.

The reader will carefully notice that these currents are only momentary and die down almost immediately, though its own inertia may keep the galvanometer-needle swinging.

73. A Current Equivalent to a Magnet.—The converse of (2) above would be the moving of a circuit carrying a current by a magnet. This can be shown as follows: If a small coil consisting of several turns of copper wire have its ends inserted through a large cork and soldered to strips of copper and zinc and the whole be floated on acidulated water, it is easily shown that the coil is attracted and repelled by a bar magnet just as a small floating magnet would be. (Fig. 27.) It will, in fact, be equivalent to a very short magnet whose axis is perpendicular to the plane of the coil, and whose north and south poles can be found by the

rule that the south to north direction of the axis is related to the direction of the current as the thrust to the twist of a right-handed screw. Such an arrangement is known as De La Rive's floating battery.

Hence, not only will a current make a magnet, but it is itself equivalent to a magnet. The form of the equivalent magnet depends altogether on the form of the current. Taking a long spiral coil of wire it is equivalent to a long bar magnet whose north pole is where the current leaves the magnet if it be a right-handed spiral, and *vice versâ* if left-handed.

74. Momentary Current Produced by Motion of Another Current.—We have now seen that a moving magnet can generate a momentary current in a conductor, and, further, that a current in a circuit is equivalent to a magnet. Hence it seems probable that a current in one moving circuit may generate a current in another circuit.

That this is really so can be readily seen by inserting a spiral carrying a current into another spiral in circuit with a galvanometer and then

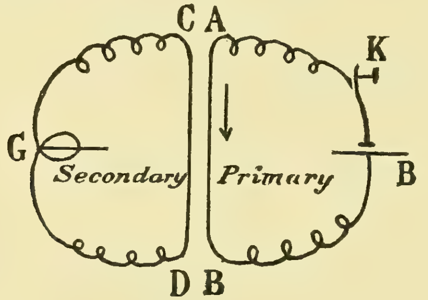


Fig. 28.

withdrawing it. In both cases momentary currents will be observed, whose directions are given by the above rule in § 72.

Such momentary currents are called induced currents.

75. Momentary Current Produced by Varying Another Current.—We do not need, as above, to move the circuit carrying the influencing current. It will serve the same purpose if we leave the influencing circuit at rest, and simply start and stop a current in it. This will be equivalent to having a steady current in it and making it approach and recede from the second circuit.

On starting the current, then, in the inducing or primary circuit, we will have an oppositely directed current induced in the influenced or secondary circuit, and on stopping the current in the primary we will have a direct current induced in the secondary circuit. The above phenomenon is often called mutual induction. It can be studied by laying two long wires side by side, putting one in circuit with a battery and key, and the other in circuit with a galvanometer. On making with the key so that a current starts in the direction A B, the galvanometer will give a throw indicating a momentary current in the direction $\overrightarrow{DC}$.

On breaking with the key the galvanometer will give a throw indicating a current in the direction $\overrightarrow{\text{C D}}$. (Fig. 28.)

76. Self-Induction.—But inductive effects are possible without a second circuit. Two different parts of the same circuit may act on one another, *e.g.*, two different turns in the same spiral. A current rising in such a spiral will act inductively on itself, tending to produce a reverse current whose effect will be shown in a retardation of the rise of the main current. This is the self-induced current at "make."

Again, on stopping a current in a circuit, a momentary direct current will be produced, and its effect will be manifested in a tendency to prolong the life of the dying current. It is obvious that the effect of both, then, is to prevent either the sudden starting or the sudden stopping of a current of electricity. A similar effect is produced in a current of liquid by the *inertia* of the matter. Hence, the above phenomenon of self-induction is sometimes referred to as the *inertia* of electricity. We shall attempt to explain later the real cause of it.

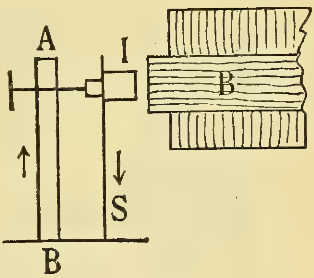


Fig. 29.

77. Ruhmkorff's Induction Coil.—A very important peculiarity of induced currents is that by using suitable secondary circuits we can get either a much higher or a much lower electromotive force than that of the primary, attended by a much smaller or much greater current, respectively. This is of great importance in apparatus which employs induced currents, such, *e.g.*, as Ruhmkorff's induction coil. An induction coil consists essentially of a *primary coil* or bobbin, which can be slid into a *secondary coil.* The primary coil usually contains an iron core, to heighten the effect. Subsidiary parts are an *interrupter* and a *condenser.* In accordance with the above remark, the secondary is made of a large number of turns of small wire, so as to largely increase the induced electro-motive force, and the primary is made of a few turns of stout wire, so as to afford a large current and decrease the effects of *self-induction.* On rapidly making and breaking the current in the primary, a succession of momentary currents, alternately reverse and direct, will traverse the secondary. This "make and break" can be best done automatically by an interrupter.

The Interrupter.—A bundle of soft-iron wires is inserted in the primary coil. When the current passes, this bundle becomes an electro-magnet, and attracts a piece of soft iron attached to a vertical spring, S. Parallel to the spring is an upright, A B, through which passes a screw, which presses against the spring, and the current of the primary is led through this upright, screw, and spring. On the breaking of the current by the attraction of I the bundle ceases to be an electro-magnet, and so I

is released, whereupon the circuit is again completed and again the current passes, and I is attracted. Thus we have a succession of momentary currents in the primary. (See Fig. 29.)

The Condenser.—This consists of sheets of tin-foil separated by dielectric sheets of paper soaked in paraffin. It is connected with the primary in such a way that (1) when the primary is broken the electricity of self-induction flows into the condenser, and so causes no spark at the interrupter; and (2) when the primary is made the condenser is discharged into it, and so causes the primary to grow very slowly, and thus greatly decreases the spark in the secondary at making of the primary.

The net result is that the currents induced in the secondary at make

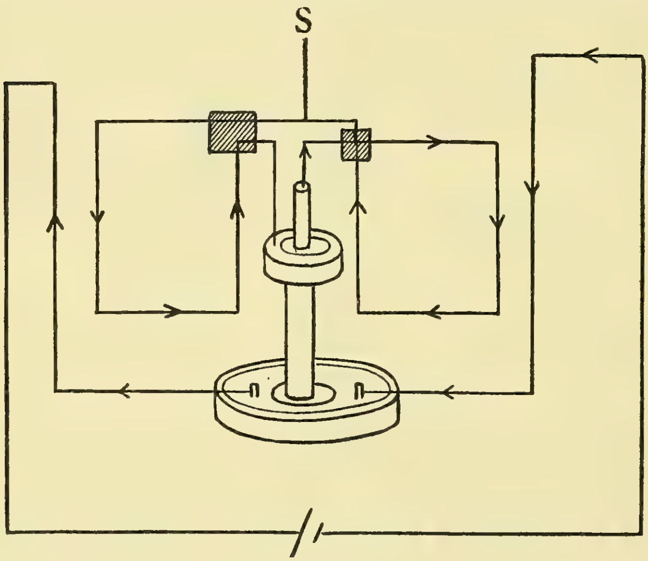


FIG. 30.

of the primary become very negligible compared with those produced at break of the primary, and so we have in effect a succession of currents in the same direction and of very high potential.

78. MAGNETO-ELECTRIC MACHINES.—So far as the generation of a current in a coil of wire is concerned, it makes no difference whether we move the magnet and keep the coil stationary or move the coil and keep the magnet stationary. The only thing requisite is *relative* motion.

In a magneto-electric machine two parallel bobbins of wire, each containing a soft-iron core, are whirled rapidly around an axis midway between them. Thus the bobbins come alternately in front of the poles of a poweful permanent magnet, and thus the cores are rapidly magnetized alternately in opposite directions, and so on in a circuit including both the bobbins alternate currents are generated in rapid succession. A *commutator* attached to the rotating axis reverses the currents at

every half revolution, so that all the currents are turned in the same direction.

79. Attraction and Repulsion of Currents.—Since magnetic poles attract and repel each other, and currents even in straight conductors have magnetic fields of force, it is natural to expect that currents will exhibit attractions and repulsions.

Ampère was the first to establish the laws of such attractions and repulsions. His conclusions as to all currents can be readily verified by such a simple apparatus as is shown in Fig. 30.

It will then be found that the currents attract each other where running in the same direction and repel where running in opposite directions.

The laws for oblique currents can be readily deduced from the foregoing. For if two parallel currents be shifted so as to become somewhat inclined to each other, then they will both run away from, or one away from and the other toward, the common apex, according as they were formerly, in the same or in opposite directions, respectively. Hence, oblique currents attract if both run away from the common apex, and repel if one runs away from it and one toward it.

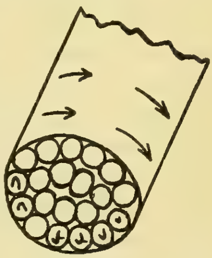


Fig. 31.—North Pole.

80. Ampère's Theory of Magnetism.—Before proceeding to consider what electricity is, we may first get magnetism out of the way by reducing it to electricity, and here we are treading on pretty firm ground. For it will be remembered that in § 34 we saw strong reason for believing that even the ultimate particles of a magnet were magnets also. Now, absolutely all the behavior of a magnet can be imitated by an electrical current in a circle or helix. Hence we have a strong hint that the ultimate particles of a magnetic substance contain little circulatory currents, which, just like larger ones, ape the behavior of a magnet.

It will be remembered that the magnet to which a circular current was equivalent had its axis perpendicular to the plane of the current. Hence, according to this theory magnetization consists in making these molecular currents wheel all facing the same way with their planes perpendicular to the length of the magnet which they make up, *i.e.*, with their planes perpendicular to the lines of magnetic force.

We cannot take space to enumerate the numerous, almost conclusive arguments for this theory. One only we shall mention,—a remarkable phenomenon discovered by Faraday. Light that has its vibrations reduced to one plane is said to be plane polarized. Now, there are certain crystals and solutions that have a peculiar effect on such light, namely, they rotate the plane of polarization. Faraday discovered that when plane polarized light was passed through certain substances (notably, "heavy" glass) which were in a strong magnetic field, the direction of the rays of

light being the direction of the lines of force, a similar rotation of the plane of polarization took place. But there was a remarkable difference between the two cases. If the light were reflected back through the crystals its twist would be taken out, but if the same thing were done with the light rotated magnetically the twist would *be doubled.* This can only be explained on the supposition that in the magnetic field there is some kind of rotation going on around axes parallel to the lines of force.

What is Electricity?

81. Nature of Answer.—It is well to realize at the outset exactly what answer may be expected to the question, "What is electricity?" Since certain famous experiments performed by Dr. Hertz, of Germany, a few years ago, it has been a common popular mistake to suppose that we know what electricity in its essence is. This is as serious a mistake as to suppose that the establishment of the kinetic hypothesis tells us what matter is. What each does is simply to let us have a faint glimpse into the mechanism by which electrical and material phenomena are brought about; that is all. About what electricity is we *know* as yet practically nothing, and probably will never know fully. But we do now know positively something of the way in which certain electrical phenomena, chiefly those treated under the head "Electrical Radiation," are brought about. In a word, what electricity is has only been answered by certain dim speculations; but assuming a something, we know not quite what, called electricity, we can pretty clearly explain certain electrical phenomena.

It would, perhaps, be more satisfactory to take up the known and clearly settled first, and then indicate the unsettled speculations; but this would necessitate an order that would be likely to confuse the reader, so we shall take the subject up in the logical order, and take care to point out the known and the doubtful.

82. Electricity is not Energy.—A common answer to the question, "What is electricity?" is, "Electricity is a form of energy." In preceding sections we have frequently spoken of electrical energy, or energy of electrification, or energy of the electrical current. But none of these phrases imply that the electricity itself is energy, just as though two masses attracting each other gravitationally (such as the earth and the moon) form a system having a certain amount of potential energy, and matter in motion has kinetic energy, yet in neither case is the matter itself energy. Similary, two so-called charges of electricity attracting and repelling each other form a system having potential energy and electricity in motion has kinetic energy; yet in neither case is the electricity itself energy.

Again, the energy of a charged conductor is the work we would have to do in charging it. Its potential, V, is the work done in bringing unit charge up to it from a place of zero potential. The work done in bringing Q units up will then depend on the product Q V. Hence, the

energy of the charge is proportional to the product Q V. Hence, it is obvious that the charge Q itself cannot be energy. In this respect it differs markedly from heat. The energy of a charge of heat does not depend upon its temperature; it is the same whether it is heat in a warm body or heat in a cooler body. The heat itself *is* energy.

83. Electricity is a Thing, for it is Conserved.—In § 3 we stated that the test of a thing was whether it was conserved or remained always the same in quantity. If all the cases of electrification and flow of electricity that we have discussed be carefully considered, it will be found in all cases that electricity will stand this test. In the first place, this is evident as regards a voltaic current, for no such current will flow except in a closed circuit. If the circuit be not completed, but the gap be not too great, the current will jump across the gap, and so complete the circuit. In any other case there will be no flow. The electricity, in fact, behaves as a perfect and incompressible fluid.

In the second place, as regards a static charge of electricity,—as, for instance, a charge given to a Leyden jar from an electric machine,—it may be objected that here we have, for the time being, a flow into the condenser without any complete circuit. But here, too, we can show that there is a circuit completed, and that the electricity still retains its similarity to an incompressible fluid.

84. In Charging a Conductor Electricity is Elastically Strained Outward.—In § 29 we saw a remarkable parallel between the charge and discharge and the various residual charges and discharges of a Leyden jar, on the one hand, and the phenomena shown by elastic bodies when distorted, on the other hand. This in itself was enough to strongly support the view that the charging of such a jar meant setting up an elastic strain in the dielectric which separates the coatings, and that its discharge meant relieving this strain. Thus, the most important part in the whole phenomena is played by the dielectric.

To enable us to think of the matter more clearly, we shall use the following analogy, which represents the state of affairs very well and may be, probably is, much more than a mere analogy. We shall think of electricity as an incompressible fluid, filling all space, and a *dielectric* as a kind of elastic jelly in which what we call electricity is imbedded or entangled. Now, a property of such an arrangement would be that, if we tried to displace the electricity, we would meet with a certain amount of elastic resistance from the jelly, and when we released the particles from the distorting forces they would be immediately drawn back nearly to their original positions by the elastic force of the jelly. This is what takes place in charging a conductor. Electricity is forced into it, but acts like an incompressible fluid, so that in the conductor itself no change of density of the electricity is produced, but at the surface electricity is forced out into the dielectric, setting up such a strain as we have referred to above. This, it will be observed, accounts

for what we referred to in § 21, that electricity resides only on the surfaces of conductors. For we conceive of a conductor as permitting the electricity to flow freely through it, so that in the conductor there is neither strain nor condensation. Hence, in the body of the conductor there will be no change produced and the charge will only be manifested as elastic strain at the surface.

But the electricity in the dielectric is incompressible, so that when any layer of it is displaced outward it must displace the next layer outward, and so on. Where, then, will the process stop? Evidently, it will only stop when the strain reaches the surface of another conductor from which electricity has been withdrawn. Some electricity will, consequently, be forced into the conductor. But how does this conductor come to have a deficiency? Electricity must have gone from it to somewhere. If the whole process has been confined to these two conductors, evidently what has been taken from B must have gone to A. In other

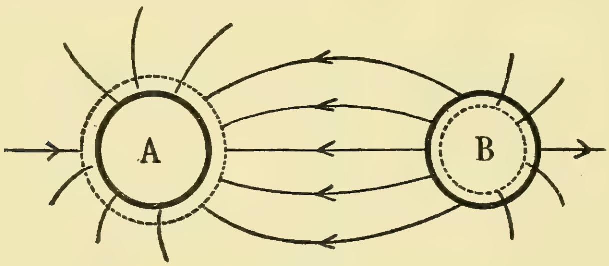


FIG. 32.

words, A has been charged positively and B negatively, and again the flow has been in a closed circuit from B to A by the machine and back to B by the dielectric. So A and B each contain as much electricity as at first, but the dielectric is in a state of strain, which will immediately force the electricity back from A to B, if we connect the two by a conductor.

85. Static Electrification is Potential Energy.—In § 8 we saw that an elastic spring, when stretched, tended to shorten and so do work, and so it possessed potential energy. In the same way, the strained dielectric separating two charged conductors is in a state of elastic distension, and contains, therefore, potential energy.

86. Paramount Importance of the Dielectric—No Action at a Distance.—The reader will notice that in the preceding the leading rôle is played by the dielectric or the non-conducting medium between charged bodies. It is, in fact, the dielectric that is charged, not the conductors. This recognition of the part played by the dielectric is what distinguishes the old one-fluid and two-fluid theories from the theories we now adopt. The older theories viewed the charges on two conductors as acting on one another directly at a distance, *i.e.*, without any assistance from the

intervening medium. From the time of Newton down, physicists have disbelieved in this action at a distance, though admitting it as a mathematical fiction. They believe now that when any two bodies act on one another,—viz., two conductors charged with electricity, two heavenly bodies (such as the sun and earth), or two magnets,—in all those cases the action is to be accounted for by considering what is happening in the intervening medium.

Direct action at a distance and action by an intervening medium should differ in this way: If a body acted on another directly at a distance, such action should be propagated instantaneously; whereas, if the action took place by means of the intervening medium, such transmission should not be instantaneous, but should have a finite velocity. It becomes, then, of the utmost importance to settle whether electrical effects are propagated with a measurable finite velocity. How this has been settled will be explained later (§ 92).

87. Function of a Machine, Battery, or Dynamo.—We see, then, that a circuit of wire is just as full of electricity when no current is circulating in it as when a current is circulating in it. The difference lies in the fact that in the latter case electricity is being pumped around the circuit by means of the "generator," as it is mis-called.

In the case in which a condenser is being charged, part of the flow consists in elastic displacement through the dielectric. This displacement will continue until the elastic reaction is equal to the displacing force, when the flow will stop, or until the strain in the dielectric ruptures the dielectric, producing a disruptive discharge.

88. Process of Conduction in Solids.—In a dielectric we can set up a state of strain with a tendency to spring back. In a conductor, though we may attempt to set up such a strain, it will be unavailing. It will break down as fast as set up, and thus the electricity will be handed on by a series of instantaneous disruptive charges, constituting a continuous flow in the conductor.

For clearness we may liken the process to the flow of water in a tube full of marbles. It will experience a frictional resistance to flow, and Ohm's law if interpreted tells us a remarkable thing about this resistance. For by Ohm's law the force urging the flow is proportional to the flow. Now, if there were no force opposing the flow the flow would not go on at a steady rate, but at an accelerated pace; or, if the force urging the flow were greater than the force opposing the flow there would still be a resultant force forward, and still an acceleration of the pace. Now, since there is no acceleration of the pace after the flow has become steady, it is evident that the urging and retarding forces must be equal; and since the urging force is proportional, accurately to the flow (which is Ohm's law), the retarding force must also be accurately proportional to the flow, or the frictional resistance is proportional to the first power of the speed. If we contrast this with the frictional resistance of the air to a falling

body, we will see that it is a remarkable result, for at low speeds the air offers a resistance proportional to the first power of the speed; at higher speeds the resistance is proportional to the second power, and at still higher to the third power. But in electrical flow the resistance is always proportional exactly to the first power of the speed.

Now, when work is done against friction heat is produced. It is readily seen that the heat so produced when a current of electricity is forced along in opposition to friction will be proportional to the amount forced along in a certain time, *i.e.*, to the current. And it is also evident that the work is proportional to the force overcome; or, since this force overcome is equal to the driving force, the work is proportional to the driving force or electro-motive force acting. Hence, on the whole, the heat produced in the conductor, which represents this work done, is proportional to the product of the electro-motive force and current (*i.e.*, to E C), which is Joule's law (§ 65).

89. CONNECTION BETWEEN CONDUCTION OF HEAT AND OF ELECTRICITY. —It is very evident that there is some close connection between the conduction of heat and that of electricity. For, as has been stated (§ 46), the heat conducting and electrical conducting powers of bodies run exactly parallel, or are exactly proportional. Moreover, substituting temperature for potential and quantity of heat for quantity of electricity, Ohm's law holds as accurately for heat as for electricity. Again, both spread out from a centre in a conductor on all sides, or are of the nature of diffusions.

Now we know that heating a body means quickening the *motions* of its particles, and we see that forcing electricity through a body heats it, or quickens the motions of its particles. This lends strong support to the idea that electricity is transmitted by to-and-fro vibrations of the particles of the conductor. A greater velocity of transmission will require a higher rate of motion of the particles, and this means an increase of temperature in the body, which is exactly what observation shows to attend an increase of current in a conductor. This seems highly probable as far as it goes, but must not be trusted to as anything but a hazy approximation to a complete explanation.

90. ATOMIC UNIT OF ELECTRICITY.—We saw by Faraday's law of electrolysis (§ 56) that if a quantity of electricity passed through an electrolyte, the quantity (by weight) of an ion it took with it depended on the atomic weight of the ion and its valency, and was proportional to the atomic weight divided by the valency. Now, since atomic weights mean the relative weights of the atoms, if we take weights of two substances in proportion to their atomic weights, these quantities must contain the same number of atoms. Hence, Faraday's law means that the passage of a certain quantity of electricity brings the same number of atoms to the electrodes, no matter what the substance is, except that in the case of a divalent element only half as many are brought, in a trivalent only

one-third as many, etc. This evidently amounts to saying that each univalent atom carries a certain amount of electricity, each divalent twice as much as a univalent one, each trivalent three times as much, etc., no matter what the substance may be or what the weight of the atoms.

Calling the charge carried by a univalent or monad element the atomic unit of electricity, a dyad atom carries two atomic units, a triad three, etc. This, then, is a natural unit of electricity. An atom of a substance is a perfectly definite mass of it, and now we see that each atom carries a perfectly definite charge of electricity, which charge is simply the atomic unit of electricity multiplied by the valency of the substance.

Magnitude of the Atomic Unit.—From the roughly-known number of atoms in a certain quantity of gaseous ion set free by a known current of electricity we can calculate roughly the size of the atomic unit. It turns out to be about the hundred-trillionth part of a coulomb. This is an exceedingly small quantity, but we have to remember the smallness of atoms of matter and their nearness together. If we compare the electrical attraction between them or their chemical affinity with the force with which they would attract each other according to the ordinary law of gravitation, we find that the electrical attraction is ten thousand million million million times the greater!

91. Chemical Affinity an Electrical Phenomenon.—Hence, a remarkable parallel between the atom of matter and the atomic unit of electricity. The atom of matter is (for the same substance) of invariable weight, and is the smallest quantity of the substance we ever have to deal with. The atomic unit of electricity is an invariable quantity, and is the smallest quantity we have to deal with. Moreover, every univalent atom of matter carries one atomic unit of electricity, every divalent atom of matter two atoms of electricity, etc. Thus, the valency of an atom is simply proportional to the number of atoms of electricity it carries.

The question at once suggests itself, May not the valency be caused simply by the number of units of electricity the atom carries?

A dyad atom (*e.g.*, O) attracts to itself two monad atoms (*e.g.*, H), giving H_2O. It will take neither more nor less than two. Now, a charge of two negative atomic units of electricity on O would attract the unit charges of positive electricity on *two* atoms of H, neither more nor less. Thus, electrical attractions account for "chemical affinity," and there can be but little doubt that this is the true explanation.

92. Propagation of Electro-magnetic Influence.—We have so far been referring to what goes on in the transmission of electricity from place to place along a conductor; but we had several instances of a current producing effects across the dielectric surrounding the current. For instance, a current acts on a magnet separated dielectrically from it, and even where there is no magnet it sets up a field of magnetic force. Again, a current induces a current in a neighboring circuit separated dielectric-

ally from it. So that a current exerts both electrical and magnetic influence across an intervening dielectric. These phenomena are called electro-magnetic inductions.

Now, in § 86 we referred to the two possible views of this action: (1) that it was direct action at a distance; (2) that it took place by an intervening mechanism. We proceed, then, to show that the latter is the true explanation,—that, in fact, electro-magnetic induction is a wave phenomenon propagated through the medium in successive pulses, some-

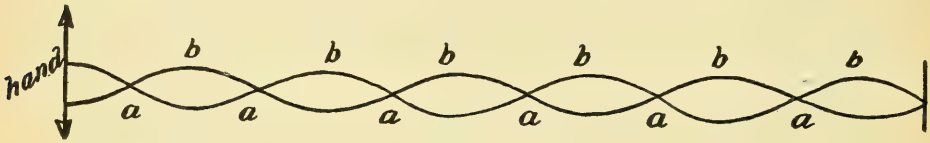


Fig. 33.

what like water waves on the ocean, or sound waves in air. But for the moment we shall offer no description of the nature of the wave. The question simply is, Is it wave motion?

93. Interference.—One of the striking properties of waves is that they can interfere so as to annihilate one another at some places and re-inforce one another in other places. Any one who has watched two systems of water waves coming from different directions around a headland and meeting knows that at some places they produce a calm, namely, where the crests of one system fill up the troughs of the other, and at other places they produce waves of double height, namely, where crest falls on crest. The same is true if waves are reflected from a vertical cliff: the direct and reflected waves interfere, producing similar effects.

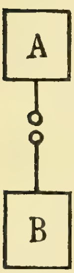


Fig. 34.

To take another example, any one may, by tying an end of a long rubber tube to a distant wall, stretching it out, and moving the end in the hand rapidly up and down, produce an interfering system of direct and reflected waves. In the system so set up it will be observed that certain points (a) are always at rest, and certain other parts (b) always in motion. The former are called *nodes*, and the spindle-shaped parts between the nodes are called *ventral segments* of the stationary waves. (Fig. 33.)

A complete wave-length is twice a ventral segment in length. Now, interference is a characteristic of all waves, and if electro-magnetic induction be a wave phenomenon it must show the same.

94. Vibrator and Resonator.—The difficulty, however, in testing this question is how to start suitable waves, and how to detect and measure them. In the first place, we must have something corresponding to the hand in the above to start vibrations. This we shall call the vibrator. Its vibrations must not be too slow, or the waves will be too long to deal with.

Now, if we take a pair of conductors, as in Fig. 34, and highly charge one, it will discharge through the knobs to the other, but the action will not stop there. Just as in the case of the oscillating discharge of the Leyden jar, there will be a return rush from B to A, then again from A to B, etc. The periods of these return oscillations will be exceedingly short. If the plates are about sixteen inches square, the oscillations will number thirty millions per second.

Now, how to detect the waves: here we make use of the principle of resonance. If an organ-pipe be tuned to exactly the same pitch as a tuning-fork, then when the tuning-fork is sounded at the mouth of the pipe the latter will sound in sympathy. What is called the frequency of vibration is the same in both fork and pipe, and the pipe is said to *resonate* to the fork. How can we get an instrument that will sympathize with an electrical vibrator? The most natural would be a plain circle of wire (Fig. 35), of such a length that the currents induced alternately in opposite directions by our vibrating primary currents would run around in the same time as the original vibrations. What length it will need to be will depend altogether on how rapid the vibrations of the vibrator are. With the plates mentioned above seven feet is a suitable circumference for the resonator. How, finally, are we to observe the oscillations of the induced currents in this resonator? By making a small gap in it, and noticing the currents dashing across the gap in a spark when, after a few concurrent rushes, they have gained sufficient volume.

FIG. 35.

Now, we are prepared *to feel for* the electro-magnetic waves. The vibrator is set up vertically, a reflecting sheet of zinc set up at a distance parallel to it. Just as in the waves reflected from the wall along the

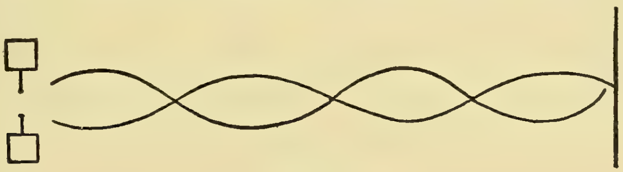


FIG. 36.

rubber tube the electro-magnetic waves will be reflected from the zinc, and, interfering with the direct waves, will produce stationary waves. At the nodes of these waves the resonator shows no effect, but at the loops it sparks. Doubling the distance between two consecutive nodes we have the wave-length, or the distance traveled by the disturbance during one complete vibration of the vibrator, and, multiplying by the number of vibrations per second, we have the velocity with which the disturbance travels.

95. ELECTRO-MAGNETIC THEORY OF LIGHT.—The velocity thus determined turns out to be practically the same as that of light, and this is a

strong confirmation of the theory otherwise almost proven, that light waves are simply electro-magnetic waves, but of immensely smaller length than any ordinary electro-magnetic waves. Light waves are less than one-forty-thousandth inch in length, whereas the waves obtained as described are several feet or even hundreds of feet long,—a difference, it is true, immensely greater than that between the waves given by the highest note of a piano and the lowest note, but still a difference merely of degree, not of kind.

How could we get real light waves in such a way? By taking a vibrator rapid enough, *e.g.*, a Leyden jar small enough. If we calculate what the size of such a Leyden jar would be, we find its size about the size of a molecule, which has been otherwise roughly determined. This suggests that light waves are electro-magnetic waves excited by electric oscillations in the molecules of incandescent matter. But it is not necessary to imagine the atoms discharging like Leyden jars, nor yet to imagine that the electrical oscillations are pulses of electricity rushing backward and forward from end to end, as it were, of the atom, like the oscillations of water in a trough when one end has been raised and dropped. We know that the atoms are in vibration, their vibrations constituting heat; and these atoms being charged, the charges vibrate to and fro along with the atoms, and thus constitute alternating currents.

96. MAXWELL'S PROOF OF THE IDENTITY OF LIGHT AND ELECTROMAGNETIC WAVES.—Though Maxwell could not measure the velocity of such waves directly, he deduced from his theory a formula for the velocity, in terms, of the inductive capacity of the medium and its *magnetic permeability* which, on being filled in with the values of these constants for different media, gave practically the same number as that which expresses the velocity of light.

His formula may be very briefly explained thus: Newton showed that the velocity of sound waves in a medium of density (d) and elasticity (e) is

$$V = \sqrt{\frac{e}{d}}$$

Now, it will be remembered that κ, the specific inductive capacity of a medium, is proportional to the capacity of a jar, with that medium as dielectric. This capacity is greater the greater the electric displacement the medium allows, and this electric displacement varies inversely as the elastic resistance to displacement; so that the specific inductive capacity appears as the reciprocal of the elasticity. Hence, in the above formula we write $\frac{1}{\kappa}$ instead of e.

Again, the magnetic permeability of a substance can be shown to be analogous to the density of ordinary matter; and this magnetic permeability, which is simply the ratio in which a magnetic field is strengthened at any point by the presence of that substance instead of air at the

point, is readily determined by proper methods. It is usually denoted by μ. Thus, the foregoing formula of Newton's becomes, for the case of electro-magnetic waves,

$$V = \sqrt{\frac{1}{\kappa\,\mu}}$$

Now, the velocity of light in various substances is deduced from their refractive indices, and so we can test the agreement between these two velocities. This agreement, though not perfect, is close enough to form a convincing proof of the theory.

97. Vibrations constituting an Electro-magnetic Wave.—When a current is started in a conductor, $\overrightarrow{AB}$, it immediately sets up a field of magnetic force, and we saw that the lines of force of this field were circles inclosing the current (§ 38). Now, it is proven that this magnetic influence of the current spreads out not instantaneously, but with a

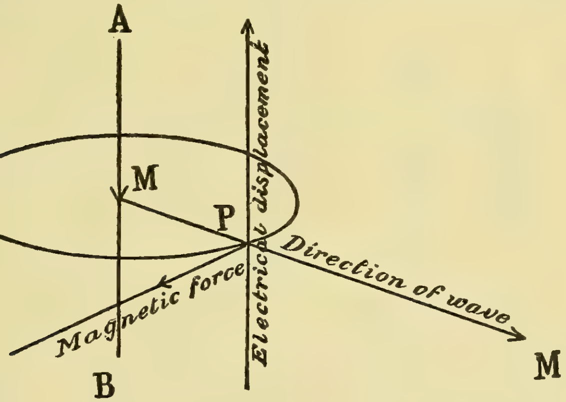


Fig. 37.

measurable velocity, namely, that of light. We may represent this by thinking of the circles widening out with that speed in all directions. The circles are always perpendicular to the radial direction, such as M M, in which they are carrying the magnetic influence of the current. Now, this direction is the direction in which the waves travel, the front of the wave being, of course, at right angles to the direction in which it is traveling. Hence, the lines of magnetic force lie in the front of the advancing waves.

Again, the growing current has an electrical influence such that, wherever it finds a conductor, it will set up a (momentary) current in it in a direction opposite to itself; or, at a point where it finds a dielectric, it will set up a strain in the dielectric, the direction of the strain being opposite to that of the original current. This direction, also, is perpendicular to the direction in which the wave travels; that is, it lies in the front of the advancing wave. But at the same time it is perpendicular to the (circular) lines of magnetic force.

Now, it will be remembered that the current in the vibrator is one that frequently has its direction reversed. Whenever the direction is reversed the direction of the electrical displacement at P is reversed and likewise the direction of the magnetic induction. These are the two vibrations that together constitute the advancing wave, viz., a vibration of electrical displacement perpendicular to the direction of motion of the wave, and a vibration of the direction and magnitude of the magnetic force perpendicular to both the others.

How to picture these two vibrations and their co-existence is a difficult problem, but it may be simplified by means of the following analogy due to Maxwell.

98. Mechanical Model illustrating Electro-magnetic Waves.—There is the most complete proof that wherever magnetic force exists we have something rotating about axes parallel to the direction of the force. This proof is supplied by the rotation of the plane of polarized light on traversing a magnetized medium parallel to the lines of magnetic force. Maxwell describes the field as filled with *molecular vortices* rotating around the lines of force. These rotating parts are also elastic and compressible. Let us think of two wheels—M and M′—of India rubber representing two of these magnetic vortices, with another smaller wheel between them representing a particle of electricity and tethered by springs on either side. Suppose M set in rotation clockwise by an electro-magnetic wave reaching it, M will then tend to turn E and E to turn M′. But M′ has inertia and will not be started all at once. Hence E in its effort to start M′ will be by the reaction pulled downward, thus stretching the upper spring. Then it gets M′ into rotation in the same direction as M's rotation. Thus we have a representation of magnetic rotation and electrical displacement.

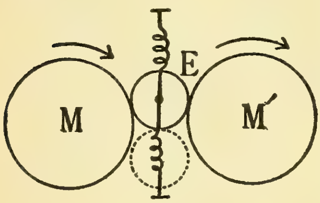


Fig. 38.

What happens next depends on whether the current that started this field is a steady current or whether it is a rapidly alternating current. If the latter, what happens is this: The rotation of M and the displacement of E reach maxima, and then when the current decreases and reverses the rotation of M ceases and reverses, thus dragging E up and gradually setting M′ also into rotation in the opposite direction. Thus, for every reversal of the current we have a reversal of the rotation of the Ms and a reversal of the displacement of the Es, and so the electro-magnetic wave is propagated.

It will be noticed that the axes about which the magnetic rotations take place are perpendicular to the plane of the paper and the direction of the electrical displacement is up and down in the plane of the paper, and so both are perpendicular to the direction M M′ of the advancing

wave or lie in the front of the wave. In this respect the model represents the wave truly.

99. Model illustrating Induction of Currents.—Suppose this magnetic rotation comes to a conductor, what happens then? In a conductor there is no elastic restraint of the electricity; so a stream of electrical particles is forced past by the rotating magnetic vortices, thus giving rise to an electric current until M′ has acquired the velocity of rotation of M and then the stream stops. So there is a temporary induced current, and it is readily seen from the model that this temporary induced current in conductor B is opposite to the inducing current in A. Again, at break of A the magnetic whirls between A and B gradually cease, but those beyond B for a moment keep on, thus causing a momentarily induced current in the opposite direction to the first one; that is, in the direction of the current in A.

Again, if we think of A itself on first making A, there is a reaction

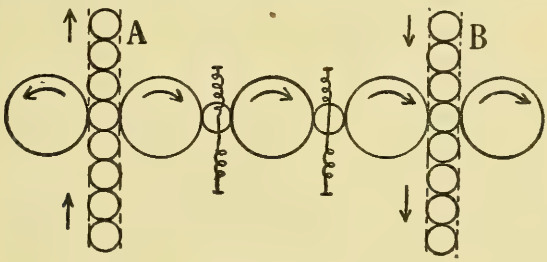


Fig. 39.

of the adjacent magnetic whirls to being set in motion, and this shows itself as an electro-motive force resisting the starting of A. At break of A the magnetic whirls keep on for a moment, thus tending to keep the current up and causing a temporary induced electro-motive force in the direction of the original primary current in A.

100. Function of a Conductor in the Passage of a Current.—We have seen that when a current is started at a seat of electro-motive force, systems of magnetic rotations and electrical displacement are started out in all directions in the surrounding dielectric. Hence, also, energy is being radiated. What becomes of this energy? Part of it passes off into space, but a comparatively small part. Most of it converges back on the conductor that is said to convey the current. There the strains break down and their energy is converted into heat energy. Thus, there is a continual flow of energy into the conducting wire from the dielectric, and so a chance given for continual new supplies of energy being given to the dielectric. When the current does work, such as turning a motor, it is not the energy in the conductor, but the energy of the dielectric in the neighborhood that is transferred to the motor. Thus, we see that the conducting wire plays the comparatively insignificant part of merely directing the flow of energy through the dielectric.

Whatever energy falls into itself is wasted as heat. The dielectric plays the all-important part of conveying the useful energy.

From this it is apparent also that electricity is urged along through the conductor not by pushes from behind, but by side forces, *rubbings*, as it were, all along the length of the conductor.

101. Dual Nature of Electricity.—We have seen that electrical effects are conveyed by the medium called the luminiferous ether. Is, then, electricity simply the ether?

Now, there are many things that strongly suggest that there are really two electricities. In electrolysis, it will be remembered, there was a separation of the atoms constituting the molecules of a liquid and a procession of the electro-positive atoms down the stream toward the cathode, and a similar procession of the electro-negative atoms up the stream to the anode. This is a strong suggestion of a dual nature for electricity, but it is by no means the strongest. Even in electro-statics such a view seems called for, by the fact that electro-static strain does not alter the volume of a dielectric, suggesting that the process consists in the displacement of something else inward.

Again, we must regard electricity as in some sense a substance, and therefore possessing inertia. Now, not the slightest trace of momentum has ever been shown by a current. Again, any one who has rotated a gyroscope and noted the difficulty of changing the direction of its axis while it is in strong rotation, knows what is meant by moment of momentum. Now, the powerful currents that can be sent around an electro-magnet should make it also difficult to turn into a new direction, unless it be that the effect of a current in one direction is neutralized by that of a current in the opposite direction. These and other facts suggest that there are really two electricities.

Since, then, the ether is somehow intimately connected with electricity, and there are probably two kinds of electricity, it may be that the two electricities co-exist in the ether in somewhat the same way as hydrogen and oxygen exist together in water. When one goes in one direction the other goes in the other direction, like the procession of the ions in the electrolysis of a liquid. In a dielectric there is difficulty in separating the components, and even when separated a short distance they will spring back, thus giving the dielectric the elastic property to which we have several times made reference. If too far separated they do not return, but fly apart, causing what we call a disruptive discharge. Again, in a conductor, the bonds connecting the two constituents are somehow relaxed, so that they are readily separated. This, however, is merely a guess quite unverified, but looking very plausible.

ANIMAL ELECTRICITY.

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Animal electricity is a subject as wide as it is inviting. Electric phenomena have been demonstrated in connection with the development of the embryo, with the secretory processes of glands, with the heart-beat, etc. In fact, the subject has been sufficiently developed to warrant the surmise that all vital phenomena may have electric as they have chemical concomitants; though such is yet far from proven. The electricity of muscles and nerves has been investigated with great thoroughness, and will be found treated in another part of this work. When it was discovered that certain fishes possessed electric organs, these naturally became the subjects of investigation by some of the leaders in physics, as Faraday; and of electro-physiologists, including that great master and, in fact, discoverer of what is most important in the electricity of muscles and nerves, Prof. E. du Bois-Reymond.

His researches, together with the later ones of Professors Burdon-Sanderson, Gotch, and Ewart in Great Britain, make up the most valuable part of what has been achieved in this direction up to date. Were the space at our disposal for this subject not so limited it might be interesting to glance at the labors of others, imperfect as they are; but, under the circumstances, it will probably be wiser to attempt to lay before the reader, in the briefest way, an account of the methods and results of those investigators only who have most advanced the subject, and whose previous researches in kindred fields have won our confidence.

The principal-known electric fishes are the *Gymnotus*, or electric eel; the *Malapterurus*, or sheath-fish; the *Torpedo*, and several other species of rays.

The *Gymnotus electricus* is the most powerful of all known electric fishes, and may attain a length of five or six feet. It frequents the marshes of Brazil and the Guianas, and its shocks are capable of stunning, if not actually killing, the largest animals. Humboldt informs us that the direction of certain roads had to be changed in consequence of the numbers of horses annually killed as they passed through the ponds which these fish inhabited. Its electric organs consist of two pairs of long structures situated immediately beneath the skin,—one pair on the back of the tail and the other along the anal fin. The organ is made up, as is usual, of cells filled with a sort of gelatinous material, and in this creature are so small that two hundred and forty have been counted in

the space of one inch. It is estimated that about two hundred nerves are supplied to the whole apparatus, these being derived from the anterior branches of the spinal nerves, and, as applies to the nerves of all electric fishes, are larger than those supplied to other parts. It is clear that an animal capable of giving such powerful shocks is not as well adapted for nice experiments as less-powerful fishes.

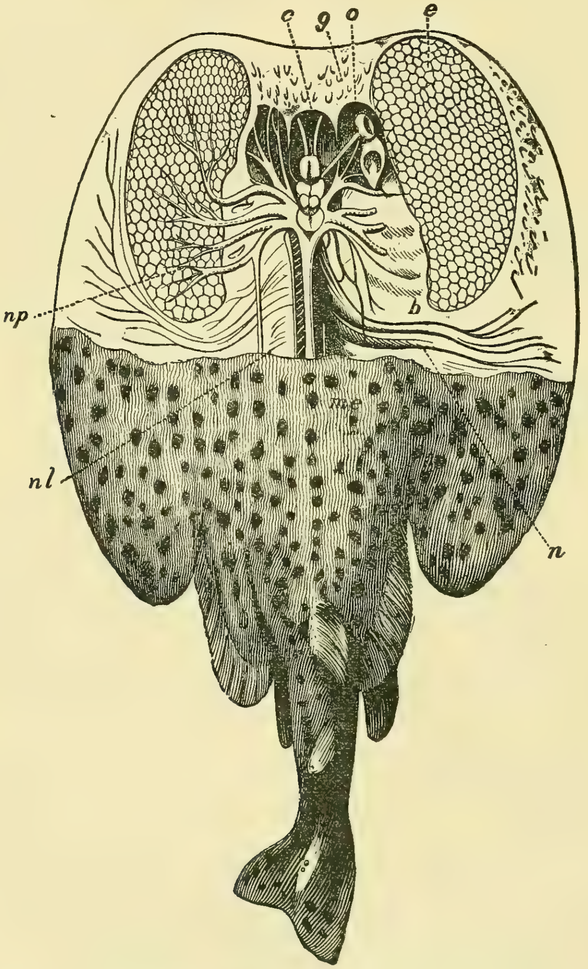

FIG. 1.—THE ELECTRIC FISH TORPEDO, DISSECTED TO SHOW ELECTRIC APPARATUS. (*Huxley.*)

b, branchiæ; *c*, brain; *e*, electric organ; *g*, cranium; *me*, spinal cord; *n*, nerves to pectoral fins; *nl*, nervi laterales; *np*, branches of pneumogastric nerves to electric organs; *o*, eye.

I. Following the historical development of the subject, we proceed to give some account of the important researches of Prof. Emil du Bois-Reymond on the tropical sheath-fish, the malapterurus. This fish is found in the rivers of Africa, including the Nile, specimens occasionally

reaching a length of four feet. The electric organ extends over the greater part of the body, lying beneath aponeurotic membranes under the skin. The cells making up the organ are rhomboidal and filled with a somewhat firm jelly. The nerve-supply consists of a single strong fibre, which gives off branches to different parts of the organ. The minute structure of electric organs will be described and illustrated later. A general idea of an electric fish may be obtained from Fig. 1.

Professor Goodsir, of Edinburgh, supplied Professor du Bois-Reymond with the specimens he first used for experimentation. They were kept in a trough constructed with a view of preserving a constant supply of fresh, well-aërated water of a suitable temperature, and were fed at first on earth-worms and later on strips of beef. The specimens were small, without barbels, young, and mostly females. The color of the fish varied with the degree of exposure to light. In darkness they became blackish, and when fatigued by experiments pale, returning to their former color after resting for a few days. They became more lively at

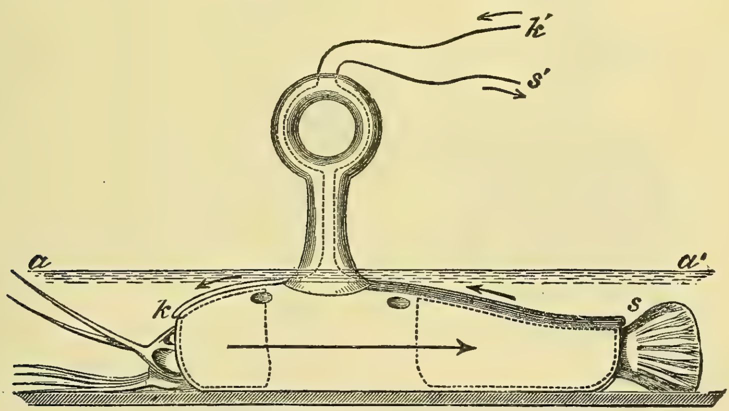

Fig. 2.

night; in fact, showed fear of light. When other fish were put in the same tank with them they immediately discharged their electric organs successively, the victims soon drifting about apparently lifeless. When left in the tank such fishes died, but if withdrawn they recovered. A frog under similar circumstances stretches out as if strychnized. In bad health the electric power was correspondingly diminished.

Method of Experiment.—The malapterurus being a fresh-water fish, not large, tenacious of life, and the electric organs supplied by a single large nerve originating in a giant ganglion-cell, is much more easily investigated in many respects than some others. Fig. 2 will give an idea of the fish, the apparatus used, etc. It will be observed that the animal is almost entirely covered with a gutta-percha case having linings of tin-foil at the two extremities, indicated by the dotted lines. These communicate by means of strips of tin-foil (*k s*) covered by insulating

material, with the handle where they are soldered to small copper plates, in which the wires end. a a' denote the surface of the water in the tank. The arrows indicate the direction of the currents.

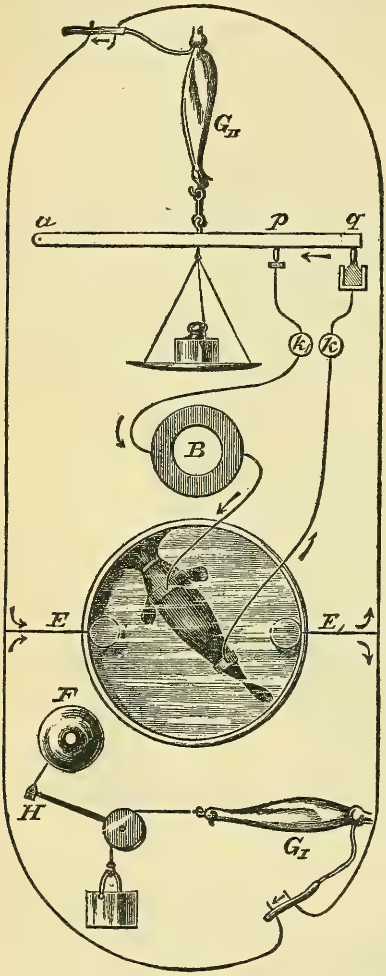

FIG. 3.

E and $E_{\prime}$, zinc electrodes in the trough containing the fish; F, H, G_1, the bell, hammer, and muscle arranged to form an alarum; a, p, q, lever of the frog-interrupter; G_{11}, its muscle; p, the platinum point which rests upon the supporting plate; q, amalgamated copper wire which dips into mercury; k, $k_{\prime}$, keys; B, galvanometer. The action of the interrupter is such that only one shock can pass through the galvanometer, for by the contraction of the muscle G_{11} the galvanometer circuit is broken at q and not again closed. The alarum, of course, goes on ringing.

Another ingenious and much-used apparatus is that shown in Fig. 3, illustrating the "frog-alarum" and "frog-interrupter," which in great measure explains itself. By means of the "frog-alarum" it was always possible to learn when the fish being experimented on gave a shock, and by the "frog-interrupter" only one shock was allowed to pass through the galvanometer, no matter how many were given. We may now deal briefly with the results of the experiments:—

Subjective Test.—By touching the head and back of the fish, or seizing it between the wetted hands, shocks varying in intensity, but powerful for the size of the animal, may be perceived.

Direction of the Shock.—As shown by the arrow in Fig 2, the current passes from the head toward the tail, *i.e.*, in a direction opposite to that of the shock of the gymnotus.

Physical Investigation of the Shock. — The principal results were: Polarization of electrodes, but no distinct electrolysis of water resulted. Passage of a spark was observed by the use of a special apparatus. Induction, magnetization of soft iron, and electric attraction were all demonstrated.

Tensions.—The poles of the organ lie at the head and the tail, and the posterior half of the organ acts more feebly than the anterior, owing to greater resistance in the former.

Relative Immunity from Electric Shocks.—Both Humboldt and

Collodon had expressed the opinion that electric fishes do not shock each other when their batteries are discharged, and du Bois-Reymond's experiments proved that the malapterurus is not affected by currents from a battery that suffice to kill other fish. The torpedo is viviparous, yet its young are not killed *in utero* by its own discharges. It appears, then, that electric fishes can withstand both their own and outside shocks; and although du Bois-Reymond discussed the reasons of this immunity, he did not satisfy his own mind on the subject. Of course, such fishes are not absolutely unaffected, and could, no doubt, be killed by a very powerful electric discharge.

The Isolated Living Electric Nerve and Organ.—It will suffice to note that such a nerve acts like any other nerve under similar circumstances,—*e.g.*, when laid on the organ of the same side and tetanized, a nerve-muscle preparation responded by tetanic contractions. Like muscle, fresh electric organ is neutral, becoming acid on standing; but when kept in warm water a short time it becomes acid, in this respect resembling the central nervous system.

II. We shall now proceed to state the results of the same physiologist's researches on the *Torpedo electricus.*

Prof. du Bois-Reymond first used for experiments specimens kept in the Berlin Aquarium which were brought from Trieste, and these were succeeded by others of a more definite character made upon fish supplied through the aquarium at Trieste. The animals used belonged to the species *Torpedo marmorata*, and were between twenty-five and thirty-six centimetres in length. They were kept in tanks in the Berlin Aquarium, burrowing in the gravel at the bottom and apparently unconcerned as to the presence of other fishes. When unconfined they eat fish of considerable size, which they first paralyze by their shocks; however, in confinement they do not seem to have taken the cut-up fish thrown into the tanks. When experiments were about to be performed they were removed from the tanks by means of a landing-net to a tub, and thence transferred to the experimental trough described below, and illustrated in Fig. 4.

The arrangement shown assumes that a shock is to be imparted to a human being; so that there are two handles in the experimental circuit, to one of which, *Hv*, the wire v' is conducted. The fish represented in cross-section is lying in a glass vessel thirty centimetres wide and ten centimetres deep, on the bottom of which there is a circular zinc plate of about the same width as the body of the animal, forming a ventral shield $v\ v^{\circ}$, a portion of which, $v\ v'$, was bent and hung hook-like over the side of the vessel. One end of the experimental circuit was brought into contact with this hook; a circular piece of flannel, $f\ f'$, soaked in sea-water, was laid on the ventral shield to prevent the edge of the dorsal shield $d\ d^{\circ}$ from touching the ventral. The specimen rests on the

flannel. The dorsal shield is an arched zinc plate with the edge turned up, the upper surface of which is lacquered and provided with a wooden knob in the middle, through which the leading-off wire, *d′ Hd*, is conducted, insulated, to the second handle. There was just enough sea-water in the receptacle to cover the back of the fish, and no more. It will be noticed that there is a frog-alarum in the circuit, the arrows, as usual, showing the direction of the current; *G* is the gastrocnemius, with its nerve; *T* the bell, *H* the hammer, and *E* the weight.

Subjective Tests.—By means of this apparatus (Fig. 4) du Bois-Reymond succeeded in giving a shock to the students in attendance at

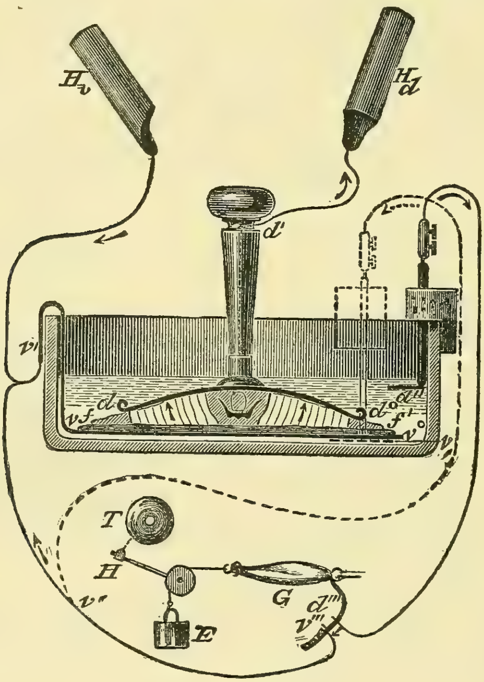

FIG. 4.

his lectures, who joined hands, after wetting them. Of course, the strength of the shock varies with the condition and size of the specimen. As a matter of fact, torpedoes seem to lose the power of giving vigorous shocks sooner in confinement than does the malapterurus.

Electrolysis of Iodide of Potassium.—By means of a special form of electrolyzer this physiologist, like Davy and Matteucci, got this salt decomposed, and, in addition, there appeared a spot at the primarily negative pole, owing to polarization in consequence of the electrolysis; so that there is a secondary current in the opposite direction to the primary, explaining the change in pole.

The Organ Current.—By this is meant, as opposed to the shock, a

current persistently generated through the electric organ, and usually in the direction of the shock. This organ current has been observed by others in the torpedo, in the skate, and in the gymnotus. Du Bois-Reymond found by the galvanometer that this current varied with the organ of the animal, and he made several measurements of its strength. According to Sachs, tetanus of the electric organ in the gymnotus weakens the current.

Secondary Electro-motive Actions of the Organ of the Torpedo and Irreciprocal Conduction.—By means of apparatus used to investigate allied phenomena in muscle and nerve du Bois-Reymond established some very interesting conclusions, which, however, may be stated briefly: "Internal polarization of the organ follows the passing of a current through it in the direction of the columns, which, like the polarization of muscles, nerves, and the organ of the malapterurus, is, under different circumstances, sometimes relatively positive, sometimes relatively negative, the conditions required for the appearance of both polarizations being generally the same in the latter as in the former." Different results were obtained, according to the direction of the current sent through the organ. This difference of strength of current must depend on either unequal electro-motive strength or unequal resistance. By "irreciprocal resistance" is meant that conduction may be better in the direction of the shock than in the opposite direction, and du Bois-Reymond was led to believe in its existence in the torpedo.

Electro-motive Actions of Electric Nerves in the Torpedo.—The eight electric nerves of this creature,—four on each side,—which can be prepared, without branches, of a length of three to four centimetres, and of an average thickness of two and a half millimetres, served admirably for the investigation of this subject. This part of the investigation was carried out by Professor Christiani, who found that the greatest electromotive force obtained was more than twice as small as that of the nerves of the frog, more than three times as small as that of the nerves of birds or of mammals, excepting the horse, and over five times as small as that of the nerves of the lobster. One peculiarity Prof. du Bois-Reymond discovered himself, viz., that the peripheral transverse section shows greater negativity as regards the equator; though it seems probable that this is not, strictly speaking, a peculiarity of electric nerves.

Negative Variations of the Current of the Electric Nerves when in a State of Activity.—Carefully-conducted experiments established the negative variation, though there were associated phenomena difficult to explain.

Prof. du Bois-Reymond's Second Investigation of Living Torpedoes.

This confirmed some previous results and developed new ones, which we proceed to give.

Electro-motive Behavior of the Skin of Electric Fishes.—Employing

the usual methods of investigation of such phenomena, it was concluded that the skin of the torpedo behaves electro-motively like that of the gymnotus, in regard to the direction as well as the magnitude of the action, and like that of the malapterurus in direction, and in all three fishes the force is probably about equal.

Irreciprocal Conduction.—This apparent irreciprocity of conduction was shown to increase with the current density, to have its seat in every transverse lamella of the preparation, and to increase with the length of the columnar track which is traversed by the current.

Resistance of the Electric Organ.—The main conclusion is that the organ conducts best in the direction of the shock, but even in that case scarcely half as well as frog-muscle parallel to the fibres, and from seven and one-half to twelve times worse than the sea-water of the aquarium, and much worse still than sea-water of the Mediterranean; but in the opposite direction to the shock, from twenty to fifty-eight times worse than sea-water.

Further investigation showed that these differences are dependent on the vitality of the organ, for as this diminishes a condition of equality in conduction—*i.e.*, resistance—is approached. The advantage, to the fish, of this state of things is obvious; at all events, so far as the direction of least resistance is concerned, and on the principles of organic evolution, it is possible to understand why development should take place, as it usually does, in those ways, and those only, which are advantageous to the individual.

Researches of Professors Burdon-Sanderson and Gotch.

It is proposed now to give an account of the researches more especially of Professors Burdon-Sanderson and Gotch, with incidental reference to the work of some other investigators, including that of Professor Ewart, in the development of electric organs. These are detailed in two papers in the *Journal of Physiology*, vol. ix, Nos. 2 and 3, and vol. x, No. 4, in which researches the skate was the fish employed, the work being done in July, 1887, at the marine laboratory at St. Andrews.

FIRST RESEARCH.

Previous Anatomical Researches of Stark, Robin, and Max Schultze.—These are summarized in the paper of Sanderson and Gotch, from which the present writer extracts. Stark discovered the electric organ of the skate in 1844. Robin made a communication to the Academy of Sciences on the same subject in 1846, and at greater length in 1865.

He describes the organ as consisting, in large skates (seventy centimetres wide), of a spindle-shaped structure fifty centimetres in length, which is placed on either side of the vertebral column of the tail. It is gray in color and semi-transparent, and is traversed transversely and lon-

gitudinally by septa, which divide it into compartments, of which the form is that of a lozenge. The cephalic proximal end of each organ is sheathed in concentric layers of muscle. By its median face it is in relation with the dorsal and ventral spinal muscles, but between these there is a space along which it touches the vertebral column, and here the blood-vessels and nerves enter it. The rounded external part of the surface is subcutaneous. The blood-supply of the organ is derived from the intervertebral branches of the caudal artery; the veins join corresponding branches of the subcaudal vein. The arteries find their way by means of longitudinal septa to the discs, to be immediately referred to. The nerves are derived partly from the anterior roots of the nearest spinal nerves, partly from the trunks of those nerves beyond the junction, and are distributed in a manner similar to the arteries until they approach the discs, where their mode of termination will be described later.

M. Robin's description of the minute structure of the organ is as follows: He regards the discs already mentioned as its essential elements. These, which are polygonal in contour and about three millimetres wide, are separated from each other by transverse septa. The anterior surface of each of the discs is smooth, the posterior alveolated. They are arranged in piles (columns), which are separated from one another by longitudinal septa, and which vary in number according to the species of the animal. The space between the alveolated surface of a disc and the smooth surface of the one behind it is entirely occupied by connective tissue containing and supporting blood-vessels and nerves, all of which go to form what M. Robin calls the "*cloison*." Each arteriole as it enters the *cloison* from the longitudinal septum divides into capillary branches, all of which tend forward and terminate in loops, which occupy the alveoli on the posterior face of each disc. The nerves, which enter the *cloison* in the same way as the arteries, at once separate from them by dividing into branches, which tend backward, to be distributed to the smooth surface of each disc. It thus appears that each disc receives its blood-supply from behind, and its nerve-supply from the front; and the separation of nerves and blood-vessels is so complete that, while in the connective tissue filling the alveoli there are no nerves, in the rich plexus of nerves covering the anterior smooth surface there are no capillaries. The substance of the disc is, according to Robin, not entered either by capillaries or nerves, and consequently their terminations never come nearer to each other than the distance between the deepest alveoli and the smooth anterior surface of the disc (one-fifth millimetre). The medullated nerves he describes as forming a plexus over the anterior surface of the discs. Each medullated fibre ends by branching into two, three, or even four filaments, and these again divide, at the same time losing their medullary sheaths, and finally their nucleated sheaths, after which they are continued as axis-cylinders. Many of these terminal branches are connected close to the surface of the disc with "nucleated multipolar

cells of irregular form." From these cells fibrils two-one-thousandths to three-one-thousandths of a millimetre in diameter tend toward the surface of the disc, dividing repeatedly, so that in longitudinal sections of the organ these nervous terminations present an appearance described by Robin as resembling bunches of root-hairs (*chevelu radiculaire extrême ment riche*). On arriving at the surface of the disc each fibre terminates in a pyramidal or conical body, from four to five thousandths of a millimetre in length, the base of which is applied to the disc. The plexus of nerves, with its terminations, separates very easily from the disc, and presents in surface-view a finely-granulated appearance, with minute perforations here and there, the granules representing the terminal pyramids. On focusing below the surface, the field appears to be beset with minute points, which are the optical sections of the terminal fibres.

The description, of which a summary has just been given, we find to be correct as regards almost all the points to which it relates. The only statements which we are disposed to question are, first, the description of compartments, which are not lozenge-shaped, but, as a rule, oblong and rectangular in section, and, second, those which relate to the multipolar cells in the nervous plexus and to the pyramidal bodies in which M. Robin believed that the nerve-fibrils terminated. To these points we shall recur in giving an account of our own observations upon the structure of the organ.

The minute structure of the electric organ was investigated in *Raia clavata*, by Prof. Max Schultze, in 1858. His attention was directed almost exclusively to the mode of termination of the nerves. He considers that the disc, the structure of which he minutely describes, owes its existence to a coalescence (*verschmeltzung*) of the terminations of the nerves, of which its intercellular substance is a direct continuation He describes the nerve-endings as constituting a fine net-work, which in the disc is transformed into a solid nervous mass, part of which can be split into laminæ, the remainder consisting of finely-granular substance inclosing nucleated cells. The chief foundation for this view of the morphological import of the disc seems to be a peculiar microchemical reaction common to the disc and nerves. Both are colored red by sulphuric acid and sugar.

M. Robin's experiments on the electric properties of the organ are of importance only in so far as they afforded for the first time experimental proof that its function is in accordance with its structure. It had previously been designated by du Bois-Reymond as "pseudo-electric," but in consideration of Robin's investigation he now proposes to distinguish it from the electric organs of the torpedo, gymnotus, etc., by the term "incomplete" (*unvollkommen*). It is, however, difficult to see that the new word is better fitted than the old one to express its character, for the organ, though small, is as perfect in structure and function as that of the gymnotus or the torpedo.

Histological Observations Made by Professors Sanderson and Gotch. —The relations of the electric organ to surrounding parts can be best understood from the engraving (Fig. 5), which represents in outline a transverse section of the tail, where it occupies most space. It is seen that its surface is mapped out into polygonal areas by the cut edges of the longitudinal septa, and that these radiate more or less distinctly from the obtuse angle on the median side of the section, which corresponds to the line of attachment along which the vessels and nerves enter. It is also noticeable that the external areas are arranged concentrically around the central ones.

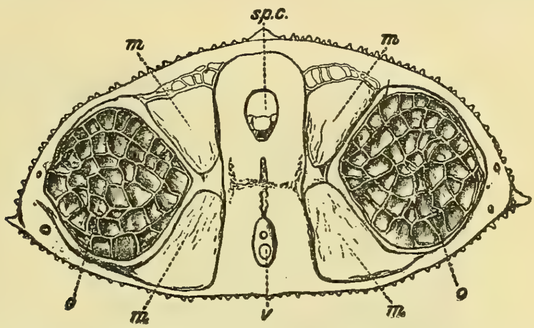

FIG. 5.—TRANSVERSE SECTION OF TAIL OF LARGE SKATE (RAIA BATIS). Actual size.

sp.c., spinal canal; *v*, vascular canal containing caudal artery and vein; *m*, muscles; *o*, electric organ.

In Fig. 6 the engraver has given the general effect of a photograph of a longitudinal frontal section, as seen under the microscope with a low power. It serves to show that the organ consists of spindle-shaped tubes, imperfectly divided into loculi placed one above the other, and each holding a disc. These tubes are so arranged that their axes are either parallel or very slightly diverge backward. The discs are, so to speak, suspended by the connective tissue which supports the blood-vessels. As has already been stated, the arterioles follow, in the first instance, the longitudinal septa by which the tubes are separated from each other. From the septa terminal arterioles pass transversely—*i.e.*, at right angles to the axis of each tube—into the spaces between each two adjoining discs, occupying a position about half-way between their two opposed surfaces. The description of their distribution, which we have given from M. Robin's memoir, need not be repeated. Both arteries and veins are accompanied by connective tissue, which in the horizontal part of their course is of sufficient strength to deserve the name of a lamina, although it is distinguished from the rest of the connective tissue, which occupies the space between the discs merely by the closer arrangement of its fibres.

On the caudal side of each of these laminæ of connective tissue and blood-vessels, and consequently between it and the disc behind it, there

exists a plexus of medullated nerves; the relations and mode of termination of which can be best seen in sections of the frozen, perfectly-fresh organ, which, after having been first placed in normal salt solution, are treated on a slide with 1-per-cent. solution of warm osmic acid. In such sections what we propose to call the *nervous lamina* is seen to be attached to the nucleated membrane which covers the anterior surface of the disc by a well-defined border. The terminal fibres which end abruptly at this border can usually be traced back to a bifurcation of the characteristic form shown, and the nerve-fibre from which the two prongs spring to a medullated nerve in the plexus already referred to. We are not able to confirm M. Robin's notion as to the nervous nature of the

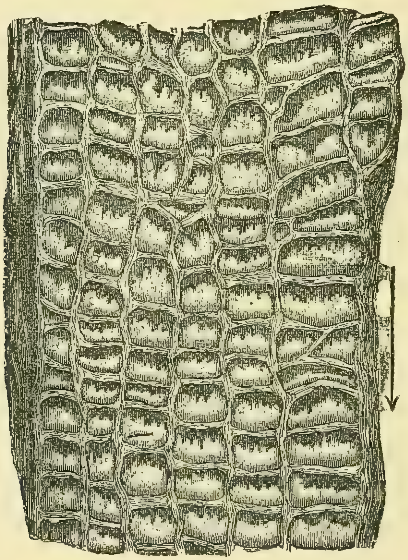

FIG. 6.—LONGITUDINAL SECTION OF UPPER PART OF ORGAN AS SEEN UNDER LOW POWER (RAIA BATIS). The arrow indicates the direction of the shock.

branched (or multipolar) cells, which are in relation with the terminal ramifications of the nerves. Some of these cells unquestionably belong to the nucleated sheaths of the nerve-fibres; others are probably connective-tissue elements. As to the mode of ending of the ultimate fibrils we are uncertain. In sections of the organ hardened in chromic acid the border of the nervous lamina exhibits a beaded appearance of very great regularity, and it can be seen that each of these beads has a terminal fibril leading to it; but no such structure can be made out in osmic-acid preparations. Whether this appearance means that the minute terminal fibrils end in the way described by M. Robin, or give off even finer branches, we are unable to state. All that we have been able to observe with certainty is that they can be traced up to, but not beyond,

the surface of the disc, and that their direction is perpendicular to its surface.

The morphological meaning of the structure described in the preceding paragraphs can only be understood by referring to its development, which has been lately made the subject of study by Professor Ewart. It is sufficient to say that, although each disc occupies the place of an undivided muscular fibre, it belongs histologically to the nervous system, not to the muscular. It is, in short, *sui generis*, and cannot be identified with anything excepting the organs of similar function found in other fish. That in several important particulars it resembles a muscular

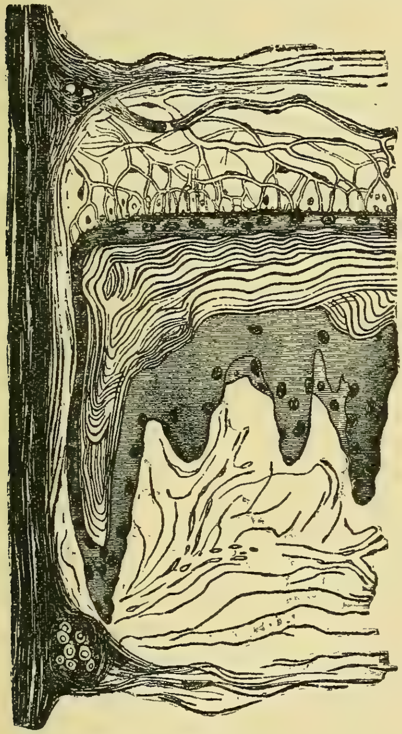

FIG. 7.

nerve-ending or muscle-plate cannot be questioned. Just as the ramifications of the nerve terminate in the end-plate without being part of it, so the myriad fibres of the nerve-lamina end in the nucleated layer which in the adult organ, but much more strikingly in earlier stages of its development, corresponds in structure with the granular nucleated substance. Physiologically the two correspond; for just as at the instant that a muscular nerve is excited the end-plates become positive to the nerve itself, so here excitation of an electric organ determines an instantaneous change in the same direction at the surface of every disc. But these considerations do not afford sufficient ground for any conclu-

sion as to the analogy between the "electric plate" and the "motor end-plate." On this point we would defer expressing an opinion until we have the opportunity of acquiring more exact information than we as yet possess as to certain of the physiological relations of the former, and particularly the influence of curare, since it is well known that in the case of the torpedo the electric organ is not affected by that poison, even though all the muscular nerve-endings are completely paralyzed.

Method of Experiment.—The skate was secured with its ventral surface downward on a board shaped like a racquet, the tail projecting along the narrow handle. The board was then plunged in a tub of sea-water, the tail being left exposed. The apparatus used to give, indicate, and record electric currents were the same as those usually employed in muscle-nerve physiology, including the capillary electrometer.

As a result of their experiments, Professors Burdon-Sanderson and Gotch draw the following conclusions, which are in harmony with experiments made on the torpedo :—

Conclusions.—1. In *Raia batis* and *clavata* an electric organ exists which corresponds in structure and function with other electric organs in fishes. It possesses the fundamental endowment by which electric organs are distinguished from other electro-motive and excitable structures, namely, that its electro-motive elements are arranged in series after the manner of a voltaic pile, so that the effects of excitation increase proportionally to the number of elements in series which are brought into action. The maximum electro-motive force of the shock—*i.e.*, the electro-motive force corresponding to one centimetre length of organ—we have roughly estimated to be about half a volt. In the torpedo it is probably ten times as much. 2. The natural discharge or shock of the electric organ consists of a succession of electric disturbances, in each of which the distal (caudal) end becomes positive to the proximal (cephalic) end. 3. A similar discharge can be evoked by exciting the spinal cord by a single induction shock, provided that the part excited is at some distance from the organ. 4. Similar excitation of the part of the cord from which the organ receives its nerves is followed at an interval of about a hundredth of a second by an "excitatory response" of extremely short duration (two- to three- hundredths of a second); this effect, of which the direction is always normal, must be regarded as analogous to the excitatory variation of a nerve when subjected to a single instantaneous excitation. 5. The passage of an induction shock through the prepared organ is followed, after an interval of about five-thousandths of a second, by a similar "excitatory response," the direction of which is always normal, whatever may be the direction of the exciting induction current. 6. The excitatory state is not propagated in the electric organ, but is limited to the part to which the excited nerves are distributed, whether the seat of excitation be the spinal cord or the organ itself. 7. In the uninjured organ there may or

may not be a difference of potential between the cutaneous surfaces covering the upper and lower ends of the organ respectively. If a difference exist it is usually in the normal direction, *i.e.*, the distal end is positive to the proximal. In the prepared organ such a difference almost always exists, and this is suddenly augmented, if present, or brought into existence, if absent, by any injury of the surface of the organ, and more particularly by momentary exposure of it to a high temperature. The effect so produced rapidly subsides, but a residue of it remains, and may last for some time. 8. When the organ is divided transversely the injured end is not thereby rendered negative to the uninjured. 9. When an induction current of sufficient strength is led through the organ it produces, in addition to the excitatory response, an after-effect which resembles, both in its constant normal direction and in its time relations, the effect produced by injury, but is of relatively small electro-motive force. It is produced by currents in either direction, but is stronger when the direction of the induction current is normal. 10. A similar excitatory after-effect, accompanied by polarization, follows the passage of a voltaic current of sufficient strength and suitable duration. 11. A similar after-effect follows the natural shock as well as the "excitatory response." We understand this to mean that just as by the action of an external current the organ is brought into a state of sub-excitation, manifesting itself in a temporary increase of the normal difference of potential between its ends, so the current of the shock or of the excitatory response produces a similar sub-excitation. There, as in the skate, we have a normal discharge of central origin; an "excitatory response" due to excitation of the nerves of the electric organ; an "organ-current" capable of being brought into existence or augmented by injury of the surface; after-effects, physiological or merely physical, *i.e.*, due to polarization; and, finally, all physiological electro-motive effects, whether they come under the designation of shock, of excitatory response, of organ-current, or of after-effect, in one and the same normal direction.

SECOND RESEARCH.

A second investigation was undertaken by the same physiologists, with a view of answering certain questions, more especially in regard to the normal reflex process by which the electric organ is discharged, and the measurement of the electro-motive force of the response of the organ to a single excitation. The results of this research will be found in the following summary of the investigators themselves:—

Conclusions.—1. Spontaneous discharge of the electric organ of the skate has not, so far as we know, been observed. A reflex discharge can always be induced by mechanical stimulation of the skin, particularly that of the dorsal surface. 2. The afferent paths by which the reflex is excited are contained, for the most part, in the spinal nerves. Although

discharges follow electric excitation of certain branches of the trigeminus, they can be evoked reflexly after all the cranial nerves have been divided. 3. The reflex discharge is always discontinuous,—*i.e.*, it consists of a group of two or more single electric effects, which follow each other with a frequency of from eight to twenty-five per second. If the stimulation is prolonged, this primary group may be succeeded by others of a similar character. 4. A reflex centre is situated in the optic lobes. Electric stimulation of the dorsal surface of these lobes produces while it lasts a discontinuous discharge of the same character as the primary reflex discharge. 5. The discharge goes on after the excitation has ceased, manifesting itself either by prolongation of the primary effect or by the recurrence at intervals of secondary effects similar to the primary. 6. Electric stimulation of the anterior region of the cord after it has been separated from the bulb also evokes a discontinuous discharge, which lasts as long as the excitation. It is followed by effects of the same kind as those which follow excitation of the optic lobes, but these are less intense and of less duration. This part of the cord must therefore be capable of automatic action, although there is no evidence that it can be excited reflexly. 7. Each disc of the electric organ is capable of developing, during the state of excitation evoked by a single induction shock, an electro-motive force of over 0.02 Daniell. The sartorius muscle of the frog (as we have found in our own experiments) is capable, when excited by a single induction shock led through its nerve, of developing an electro-motive force of 0.026 Daniell. The number of nerve-fibres distributed to the disc is certainly not less than that of the constituent fibres of the nerve of the sartorius. There is therefore no reason to regard the electric activity of a disc as extraordinary as compared with a muscle of similar innervation.

The relatively large electro-motive force which the organ as a whole is able to develop is attributable (1) to the large number of discs of which it consists, (2) to their being arranged in pile, and (3) to the nervous arrangements by virtue of which they are enabled to act simultaneously.

Addendum.—Since the foregoing pages passed into the printer's hands a most interesting paper on the origin of the electric nerves of the torpedo, gymnotus, mormyrus, and malapterurus, by Professor Gustav Fritsch, of Berlin, has appeared in *Nature*, vol. xlvii, No. 12. The reader who is especially interested in this part of the subject will do well to refer to this paper, which is admirably illustrated by photographs from nature.

The writer gives here a brief outline of the paper, without comment :—

Electric organs are of muscular origin. This is well seen in a cross-section of the tail of the mormyrus, in which instead of muscles one

finds electric tissue, only the longitudinal tendons passing outside the electric organs from muscles placed anteriorly. Again, in the electric eel (*Gymnotus electricus*) of America a similar section shows that a part of the muscle-tissue is changed into electric organs, the rest remaining unchanged. In the electric skates the electric organs are developed from muscles that originally belong to the branchial arches and the arch of the lower jaw. In all cases in electric fishes the impulses that pass along the nerves and call forth the electric discharge proceed from ganglion-cells. In the torpedo the ganglion-cells are collected in a bean-shaped mass in the medulla, forming an electric lobe, and estimated at about fifty-four thousand. In connection with these an equal number of nerve-fibres have been found. In the electric eel the electric cells form a continuous column in the spinal cord,—long and slender, and amounting probably to sixty thousand. The arrangement in the mormyrus is similar. The protoplasmic processes of the cells must have a conducting function, a remark which applies probably also to all ganglion-cells. In the electric fish of the Nile (*Malapterurus electricus*) muscular tissue is abundant and the electric organ seems to have been developed from the skin. In these the electric current passes through the body in a direction opposite to that in other electric fishes. The innumerable nerve-branches are all derived from *two* electric nerve-fibres, the structure of which is very suggestive of an electric cable, and leading inward each to a single ganglion-cell. This is of great size, having no real axis-cylinder arising from it, but, in place of it, branched protoplasmic processes join and form a kind of perforated plate beneath the cell, from which the nerve-fibre starts. Since it is clear that ganglion-cells are the real centres concerned in all kinds of electric fishes, it seems reasonable to believe that in other animals they are not merely trophic, but distinctly motor. The great value of such investigations as these is owing to the light they throw on nervous processes generally, and on the remarkable development effected by organic evolution.

BIBLIOGRAPHY.

Instead of enumerating all the original sources of information in this article, the reader is referred to "Biological Memoirs," edited by Professor Burdon-Sanderson, and to the Journal of Physiology, vols. ix and x, in which will be found a very elaborate list of references.

STATIC ELECTRICITY AND MAGNETISM.

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The state of transition through which electrical science is at present passing renders it difficult to treat the subject with that degree of lucidity which the logical mind demands. With the phraseology and, to a certain extent, the conceptions of the older theories, we are gradually rising to generalizations which tend more and more to give a new meaning to all electrical phenomena. That meaning is not yet clear enough, however, to enable us to put aside the older views and to start afresh with new terms and new definitions. We have still to accommodate ourselves to the imperfections of a transitional indefiniteness, and to employ language which the passing months are rendering obsolete. As long, however, as we endeavor to import into the older phraseology a meaning more in keeping with the results of modern discoveries, we cannot go far astray. We may still, for instance, use Franklin's, or the dual theory of electricity, if we apply to them the corrections furnished by modern science. The chief exponent of these modern views is Prof. Oliver Lodge, whose treatment of the subject will occupy our attention in the earlier pages, and will, I hope, be the means of placing the phenomena of electro-statics in a somewhat clearer light.

The ethereal theory of electricity presupposes the existence of a perfectly subtle, continuous, incompressible substance pervading all space and penetrating between the molecules of all ordinary matter which are imbedded in it and connected to one another by its means; and we must regard it as the one universal medium by which all actions between bodies are carried on. This, then, is its function: "To act as the transmitter of motion and energy." We have long known this substance or fluid as *the ether*, and to its vibrations we are indebted for the light of our planet. Professor Hertz, of Bonn, has conclusively shown that these vibrations are electrical vibrations, but electrical vibrations by reason of their short wave-length appealing to a sense-organ which we possess. We have no sense-organ for ordinary electrical waves; their length is such that the retina cannot take them up. Professor Hertz has, however, by a stroke of genius, made these electrical vibrations visible to us by simply shortening their wave-length, and has shown, moreover, that they obey all the laws of optics,—can be reflected, refracted, etc., and that they travel at exactly the same rate that light travels.

So electricity has annexed the whole domain of optics. Now, vibrations of light which we know the ether transmits must be transmitted by

something possessing rigidity; rigidity means active resistance to shearing stress, *i.e.*, to alteration in shape; it is called *elasticity* of *figure*. It is by the possession of rigidity that a solid differs from a fluid. For a body to transmit vibrations at all it must possess inertia. (Inertia is defined as ratio of force to acceleration. Transverse vibrations can only be transmitted by a body possessing rigidity; all matter possesses inertia, but fluids only possess volume elasticity, and, accordingly, can only transmit *longitudinal* vibrations.) Light consists of transverse vibrations; air and water have no rigidity, yet they are transparent, *i.e.*, transmit transverse vibrations; hence it must be the ether inside them which really conveys the motion, and ether must have properties which, if it were ordinary matter, we should style "inertia and rigidity."

This electrical ocean, in which we and everything else are immersed, has been likened by Sir William Thomson to a mass of jelly which allows all bodies to pass through it without friction, which is perfectly fluid for steady forces, but rigid for infinitesimal vibrations, and, as water is contained in jelly, so is electricity contained in the ether. Electricity thus becomes a mode or manifestation of the ether, as heat is a mode of motion of material particles. Conductors are bodies which allow electricity to flow through them,—when immersed in such a medium, they become cavities or channels. But electricity is entangled in such a medium, and through this it cannot penetrate without violence or disruption. Yet bodies can move freely through it. The electricity is alone entangled. The cavities, cracks, or spongy bodies, which are pervious, but with more or less frictional resistance to the flow of liquids through them, are the *conductors*. The insulators or dielectrics are like elastic or impervious partitions, but yielding masses, subject to strains when electricity is moved. As a general definition it may be said that *all transparent substances* (not fluids) *are insulators*, and that all opaque bodies are conductors.

By insulating, *i.e.*, supporting on glass stems such opaque bodies as brass spheres or cylinders, and connecting them by copper wire, you have so many cavities and tubes in an otherwise "continuous elastic and impervious medium, which surrounds us and them, and extends throughout space wherever *conductors* are not." But we must remember that all—cavities as well as the rest of the medium—are full of the universal fluid. We see that if matter were perfectly conducting, electrostatics would be impossible. It is by pumping electricity from one place to another, at the same time straining the elastic walls between conductors, that we make static electricity manifest. There are different ways of making the presence of electricity manifest: 1. By mechanical means, as friction, pressure, concussion, cleavage, or mere contact. The latter seems the essential element. This includes the domain of static, frictional, or Franklinic electricity. 2. By chemical means; this includes voltaic, galvanic, or dynamic electricity. 3. By means of heat and mag-

netism; this includes thermo-electricity and magneto-electricity. It must be remembered that the electricity made manifest by these different methods is exactly the same electricity, and differs merely in intensity and quantity.

Whether the ethereal theory of electricity will satisfy all the requirements of a scientific age or not, I think we can, without hesitation, accept the fact that electricity behaves exactly as an incompressible and inextensible fluid would behave. It is not meant for a moment that it is a fluid in the ordinary sense of the word, but that the different methods enumerated are merely forces applied in moving it freely through conductors and straining insulators or dielectrics, and, if the force applied is strong enough, bursting the walls confining it.

Electricity always flows in a closed circuit; it is of the utmost importance to always remember this. A cable across the Atlantic is like an India-rubber tube already full of water, with both ends opening into the common ocean at their destination. A force-pump may be used to force a certain quantity of water out at one end, but just exactly the same quantity enters at the other end; so we see that the ocean is equally as much a part of the circuit as the tube. Electricity obeys exactly the same laws; the same quantity of electricity enters at one as was forced out at the other end.

If we place a flannel cap to which a silk thread is attached over one end of a stout rod of vulcanite (both having been previously warmed), rub the cap around the rod a few times, then remove the cap and hold it near a positively-charged pith-ball pendulum, the pith ball is repulsed; the flannel is therefore charged positively (as we know, like charges repel and unlike charges attract). Present the rod to the pith ball, violent attraction ensues; therefore the rod is negatively electrified. Now replace the cap and rub again; without removing the cap, hold both to an uncharged pith-ball pendulum, and neither divergence nor attraction ensues. Thus we conclusively prove that (1) positive and negative electrifications are generated together; in fact, one kind of electrification is never produced without the other. 2. The positive electrification is exactly equal in amount to the negative. So that no electricity has been actually generated; it has been merely moved from one body to another, or we might say that electrifying a body positively is adding something to it; then electrifying it negatively to the same extent will simply mean taking an equal amount of that something from it. We have seen that when the vulcanite rod was rubbed there was a transfer of something from one to the other; in separating them a short distance there is a force exerted across the air or dielectric tending to bring them together. Faraday would have said that they are connected by lines of force, and that these lines tend to shorten and thus bring them together. At present we say that the medium between them is in a state of strain.

In an ordinary electrical machine we rub glass with some other substance, such as leather. The rubbing in this case has no special action in the transfer of the electricity; it is not the *cause* of the electricity in the same sense as it is the cause of heat. It is most likely that simple contact between dissimilar substances is the essential condition. Friction brings into close contact numerous particles of the two bodies; it also cleans, warms, and dries the surfaces; these all favor insulation, and so prevent the escape of electricity. Practically, to obtain marked electrical effects from the contact of two insulators, they must be rubbed together. When two conductors are brought together, such as zinc and copper, they are charged with electricity of opposite sign. Friction here neither increases nor diminishes the charge; as metals are conductors, the charge is instantly distributed. This charge is much more feeble than when two insulators are rubbed together. When the glass is rubbed by the leather, a transfer of electricity is effected,—the electricity on the rubber is conveyed to the earth; that on the glass accumulates on an insulated conductor, and, as it is surrounded by an insulating atmosphere, it does not escape. The electrical machine here acts exactly like a pump attached to two bodies, respectively, driving some electricity from one to the other, giving one a positive charge and the other a precisely equal negative charge. One body is the earth and the charge therefore makes little difference to it. The act of charging a conductor is analogous to pumping water into an elastic bag, or, better, into a cavity in the elastic medium that we have previously been considering; the medium's thick walls, extending in all directions, need great pressure to strain them. We now come to the most important principle in static electricity.

The Seat of Charge of Electricity is the Outer Surface of Conductors.—Consider two cavities in this elastic medium, or, better, draw them on a piece of paper and "consider fluid pumped from one to another, and you will see the charge (*i.e.*, the excess or defect of fluid) resides on the outside. If the fluid is exactly incompressible, not the least extra quantity will be squeezed by the pressure into the space originally occupied by the cavity. You may show that when both cavities are similarly charged the medium is so strained that they tend to be forced apart; whereas, when one is distended and the other is contracted they tend to approach. Further, you may consider two cavities side by side, pump fluid into (or out of) one only, and watch the effect on the other. You will thus see the phenomena of induction,—the near side of the second cavity becoming oppositely charged (*i.e.*, the walls encroaching on the cavity), the far side similarly charged (the cavity encroaching on the walls), and the pressure on the fluid in the cavity being increased or diminished in correspondence with the rise or fall of pressure in the inducing cavity."

If we take a cylindrical glass jar and coat it, both inside and outside, to within two or three inches of the top, with tin-foil, we make a

Leyden jar. Place such a jar on an insulating stand and connect either coating, by means of a chain, to the conductor of an electrical machine, and work the machine for a short time. As the coating in connection with the machine has received a charge, we should expect to get a spark if we connected the coatings together, say, with the hand. If we get a spark at all, it will be an extremely feeble one. Now let us connect as before, say, the inner coating to the conductor of the machine and the outer coating to the earth, by means of a chain or the hand. If we turn the machine as many times as before, a very strong spark will be obtained by presenting a finger to the inner coating, thereby connecting it through the experimenter's body and the earth with the outer coating. All electrical charging of bodies is exactly analogous to the charging of a Leyden jar; so we have here the key to the whole problem of electrostatics. We cannot charge one body alone, we cannot charge one coating of a Leyden jar alone; an exactly equal charge must be given to the other coating. When we charge an insulated conductor in a room, the walls and floor of such room represent the outer coating, the inner coating being the conductor; the air, with its contained ether, the dielectric, and is analogous to the glass in the jar. We have seen that we cannot charge an insulated Leyden jar. If we had a pith ball attached to each coating, both would rise equally and simultaneously when the attempt is made to charge the jar. Their levels or potentials would be equal, therefore no spark would pass. In fact, we have been trying to force an absolutely incompressible fluid into a space already full of such fluid. When we connect the outer coating of the jar to the earth we allow of the escape of just so much electricity as we pump in from the electrical machine; so, to charge a Leyden jar, for every spark we give the inner coating we must take an equal spark from the outer coating. This may be made plainer by thinking of the coatings of the jar as two India-rubber tubes (conductors) and the (dielectric) glass as an electric diaphragm uniting the tubes. The tubes are filled with water, and one end connected to a pump; we now close the end farthest from the pump by a second sheet of India rubber. If we then work the pump, the elastic diaphragm (dielectric), which does not allow water to pass, is stretched slightly, moving the water a little forward on the other side of the diaphragm, and thus to a slight extent stretching the elastic covering on the farther side of the tube. If the pump is removed, there is a small recoil of the elastic, and any extra water that has been forced in escapes again from the end of the tube which was connected with the pump. This represents the small spark from the charged insulated Leyden jar.

In the second experiment the outer coating of the jar was in connection with the earth. Therefore we must now remove the elastic covering from the farther end of the tube, and allow both ends to dip into a tank with which the pump is also in connection. It is well here to

remember that electricity always flows in a closed circuit. When the pump attached to the near end of the tube is now worked, water will be forced into the tube representing the inner coating; at the same time the diaphragm is stretched, and exactly the same quantity of water will be forced from the tube representing the outer coating. The pump may be worked so as to strain the diaphragm (dielectric) very greatly or even to burst it. If the force (pump) be now removed, we have a quick recoil of the diaphragm (dielectric), the extra quantity of water is again forced out at the pump end of the tube, the equilibrium being adjusted by the water of the tank entering the far end of the tube. In this experiment the quantity of water forced in has been much greater, the diaphragm has been stretched to a much greater extent, and the recoil (spark) has been more powerful. In the case of the jar, given a sufficiently-powerful machine the electrification may be increased until it either overflows or discharges through the glass, which would be broken in the process. If the jar is properly constructed, the tin-foil will be taken up so near the edge that the discharge, when it takes place, will occur through the air, instead of the glass, thus saving the jar.

These experiments can be also made to illustrate the process of induction. If we bring a charged body near an insulated conductor, we drive electricity of like sign to the far side of the conductor, and electricity of an opposite sign we attract to the near side. If we now connect the far side of such conductor to the earth, by means of the finger or a wire, we allow this electricity to escape, and we have two bodies oppositely charged, separated by a dielectric. The same thing occurs in the Leyden jar and its analogue, the India-rubber tube. We found that when the jar was insulated it refused to charge, but when we connected the outer coating with the earth we had the two equal and opposite charges separated by the dielectric (glass). It has been conclusively proved, by examining the glass under such conditions by means of polarized light, that it is in a condition of strain.

We have looked at electricity in the foregoing from Franklin's point of view, *i.e.*, that there was one electricity. A positive charge meant an excess, a negative charge meant a deficiency, of the universal fluid. This view seems to fit in well with the examples given of pumping an incompressible fluid into elastic cavities with thick walls, spongy bodies, and elastic bags, and thus stretching the walls. There is an obvious defect in the analogy, as the volume of the cavity is increased or diminished when we pump fluid into or out of it. We know—when we charge a conductor—that there is no change of volume in the conductor. So we have to map out, as it were, and think of the original space inside the cavity in its unchanged condition, already full of the incompressible fluid, as the true conductor. You cannot fill it any fuller, therefore the excess or defect of fluid would be on the outside, *i.e.*, in the dielectric. This might be obviated by viewing electricity as composed of two separate

entities, and not looking at negative electricity as mere negation. There are many reasons for thinking that this represents the true state of the case,—the facts of electrolysis—the two opposite processions of atoms—conveying their charges of positive and negative electricity in an electrolyte. The electrical flow in opposite directions on the Holtz machine, the strain phenomena in a dielectric, would be explained by the molecules in such dielectric being stretched by their oppositely-charged atoms, the tearing asunder of the molecules as being disruptive discharge, which is undoubtedly of an electrolytic nature ; so we would have, as in an electrolyte, two opposite processions of atoms carrying their electric charges.

Static Electricity, or Electricity at Rest, or, rather, in a State of Strain.

In the previous pages I have endeavored broadly to give a general view of the whole subject of static electricity, utilizing the ethereal electrical theory, as propounded by Professor Lodge, as a means of adding more definiteness and reality, than is given in most text-books, to electrical phenomena. We must now endeavor to treat this subject more methodically ; but I hope the general view already given will be a material aid to a more perfect understanding not only of this branch of electrical science, but also of its action on the human body.

CONDUCTORS, INSULATORS, AND ELECTRODES.

We have seen that certain bodies allow electricity to pass through them and are called *conductors*. Bodies which do not allow electricity, or allow it with difficulty, to pass through them are called insulators, or dielectrics. The metals, charcoal, water, solutions, and moist bodies, such as the earth, are conductors. Air, whether damp or dry, and all gases, including dry steam ; most kinds of glass, sulphur, India rubber, vulcanite, shellac, gutta-percha, and other resins ; some oils, dry silk, and cotton, are insulators. Wood, stone, and flax are imperfect insulators. The difference between conductors and insulators is one of degree only ; all solids and liquids resist the passage of electricity to some extent, and none prevent that passage entirely.

The insulator plays an important rôle in the application of static electricity. If the patient is not well insulated there is a great waste of electricity and the power of the machine may be quite neutralized. The most perfect insulator is a platform of glass having glass supports about twelve inches in length.

The electrodes required need not be many ; they should include a large and small brass ball, a metal point, a wooden point, and a wooden or ivory ball. A metal-cap electrode for the head is a good means of producing the souffle. The ear-electrode is made of vulcanite formed into the shape of an ear-speculum and pierced with a brass wire. In applying this

to the ears care must be taken that the sparks to be drawn should be very small; a wooden point or ball should be used in preference to metal.

MODES OF PRODUCING AN ELECTRIC CHARGE

We have seen that rubbing two different substances together is the usual method of producing an electric charge. Each substance in the following list usually becomes positively electrified when rubbed or pressed against any of the substances placed after it, but negatively electrified when rubbed or pressed against any substance preceding it in the list. We obtain the most marked effects by using pairs of substances which are far apart in the list: cats' fur, glass, ivory, silk, the hand, wood, sulphur, flannel, cotton, shellac, caoutchouc, resin, gutta-percha, metals, and gun-cotton.

Two conductors in contact, whether solid or liquid, charge one another with electricity of opposite sign. Friction between the metals neither increases nor diminishes the charge. As metals are conductors, the electricity is instantly distributed over them. When insulators such as glass or resin are pressed or rubbed together, only those parts which come into actual contact are at first electrified. The electricity in time spreads farther because the insulation is imperfect. Two insulators which have been rubbed together retain their charges unmodified for some time after their separation; this is not the case with conductors.

FORCE BETWEEN ELECTRIC CHARGES.

Bodies charged with electricity of the same kind repel one another by virtue of their charge; bodies charged with opposite electricity attract one another. The fluid with which any body is charged cannot leave the body, being retained by the surrounding dielectric; any force acting on the electric fluid acts, therefore, on the dielectric. Equal charges under equal conditions produce equal forces. We thus have the means of ascertaining whether two bodies—say, spheres of equal diameter—are equally charged with electricity; to do this we have only to observe whether, at equal distances, they exert equal forces on a third body charged with electricity. Means exist by which equal charges can be added so as to accumulate on one conductor, and we find by experiment that two equal quantities of the same sign, when thus added, attract or repel a given charge, on another body, with twice the force which was exerted by each singly, when in the same place; also that two equal quantities of opposite sign neutralize one another so as, after their combination, to exert no force. These facts enable us, independently of all hypothesis as to the nature of electricity, to treat an electric charge as a measurable *quantity*. Instruments for numerically measuring or comparing the forces due to various charges of electricity are called *electrometers*. Instruments which simply indicate the existence of a force due to a charge are called

electroscopes. The unit quantity of electricity is that which repels another equal quantity at a unit distance with unit force.

DISTRIBUTION OF ELECTRICITY ON CONDUCTORS.

Electricity, as we have had occasion before to emphasize, resides on the surface of conductors. That this is absolutely true the well-known experiment of Cavendish or Biot proves. If an insulated metal ball be strongly charged with electricity and we place two hemispherical metal envelopes furnished with glass handles on the sphere so as to envelop it, after contact with the sphere, carefully remove the hemispheres, and by means of the glass handles bring them near an uncharged gold-leaf electroscope, in each case the leaves diverge; now bring the ball near the electroscope, the leaves do not diverge, although the ball originally received the charge. We see that the charge has passed from the surface of the ball to that of the covers. This is what we should expect if we recall the experiment with the cavities in the elastic medium; "electricity being exactly incompressible, not the least extra quantity will be squeezed by pressure into the space originally occupied by the cavity." Even if the conductor be hollow and the charge be given to the inside, the result is precisely the same; it immediately flows to and over the surface. Many experiments might be adduced to prove this law.

Faraday had a cube-shaped room constructed and rendered a free conductor of electricity in every part. This chamber was insulated in the lecture-room at the Royal Institution. He went into this cube and lived in it, "used lighted candles, electrometers, and all other tests of electricity, and could not find the least influence upon them or indication of anything particular given by them, though all the time the outside of the cube was powerfully charged, and large sparks and brushes were darting off from every part of its outer surface." Mr. Boys has shown, by means of two soap-bubbles, one inside the other, that electricity did not penetrate the wall of the outer bubble, a soap-bubble being a conductor of electricity.

REDISTRIBUTION AND SUBDIVISION OF CHARGES.

If an insulated conductor is charged so as to be unaffected by other electrified bodies, and any portion of that charge be removed, the remaining electrification will distribute itself over the surface in a manner similar to the distribution of the original charge. Suppose, for example, that we have several insulated metallic spheres of equal size, one of them being charged with a certain quantity of electricity and the others uncharged. If one of the latter be brought in contact with the charged sphere it will receive half the charge; if on separating the spheres either be brought in contact with another uncharged sphere, it will receive half *its* charge, *i.e.*, one-fourth of the original charge. The distribution in each case will be uniform.

POTENTIAL.

The quantity of electricity in an electric charge is a conception analogous to that of a quantity of material fluid. So the idea of electrical potential is analogous to that of level in a body of water; that is, level as indicating a condition by which gravitating matter, such as water, can do work in descending to a lower level. The electrical potential of a conductor is that condition of the conductor in virtue of which the electricity tends to pass from the conductor to the earth, and in so passing do work,—the earth being considered at zero potential.

DENSITY.

The density of a charge at any point is the charge per unit area at that point. The density of a charge is uniform on all conducting spheres when they are unaffected by the proximity of other conductors. When the thickness of the dielectric between two conductors is variable the density of charges induced between them tends to be greater the nearer they approach. The density of any charge tends to be greater at all projecting edges or points. The electricity on any small area of an electrified surface is acted on by a force normal to that surface. This force tends to stretch the conductor outward, or tear off a part of its surface, and is called the electric *stress*, or tension, at that part of the surface. Stress or tension is measured in units of force per unit of area, and is proportional to the square of the density on the element of surface.

ELECTRICAL CAPACITY.

If we take two unequal-sized vessels and fill them with water, the quantity of water they will hold, of course, depends on their size or capacity. Similarly, if we take two insulated conductors of the same shape, but of different size, and electrify them, the large one must have a greater charge than the small one to electrify it to the same potential, —*i.e.*, the large one has a greater electrical capacity than the small one. Thus, the potential of a conductor depends both upon its charge and its capacity; in fact, if C equals the capacity of a conductor, Q the charge or quantity of electricity, and V the potential, then C equals $\frac{Q}{V}$.

CONVECTION—SPARKS; POINTS; SILENT DISCHARGE; BRUSH.

Convection occurs when electricity is conveyed from one place to another by small particles of matter, which they carry as a charge. A charged conductor can be discharged by convection if steam or spray be blown to or from it; each globule of water leaving the conductor carries away a charge of electricity. When two conductors of different potentials are brought close together, one or more sparks will pass between them. The *spark* consists of white-hot matter electrically charged. The disruption of this matter from the body is caused by the breaking down

of the strain in the dielectric; the heat and light observed are due to the mechanical action of the disruption,—as when a spark is struck by a steel upon flint, the spark is not electricity. In a conductor charged to a high potential the electricity escapes from any sharp *points* or edges. The action is one of convection by a stream of particles producing an actual current in the air, and is due to the stress at the points or edges. When the action is unaccompanied by noise or light, it is called a *silent discharge;* when accompanied by noise or light, the term *brush* is applied to the phenomenon.

As we have to deal with the human body as electro-therapeutists, it is well that we should keep constantly before our minds that if we have a patient on the insulated stool, and connected by means of a conductor to one of the poles of an electric machine, and if the other pole is also connected to the patient, the stool, or platform, while we work the machine, there seems to be no effect; we cannot get the faintest spark from our patient, yet we are moving electricity in a closed circuit; a current is flowing. It is as if an India-rubber tube were attached to a pump, the free ends of the tube dipping into the same tank. Here we are dealing with the purely conducting elements; the strain phenomena are absent, therefore we can have none of the effects of static electricity, and the current which is flowing is so small that it is not appreciated by the patient. The reason we get such a small current is that, though we have got an enormous electro-motive pressure or potential (60,000 volts; say, equal to a battery of 60,000 Daniell cells), the resistance in the machine is so great (since there are so many dielectrics between the rubber and the prime conductor) that the electricity is almost all expended in overcoming this tremendous resistance, amounting to possibly millions of ohms. But if the conducting chain in connection, say, with the negative pole be allowed to fall to the earth, and the machine worked, a different state of things is seen. The patient is charged with positive electricity; at the same time the walls or floor of the room are charged with exactly the same amount of negative electricity,—that is, the positive charge on the patient has, by induction across the dielectric, produced an equal and opposite charge.

Now, if we approach the patient with an earth-connected conductor, —that is, a conductor in connection with the walls or floor of the room,— the charge of electricity is increased; "the capacity of a conductor is increased by bringing an earth-plate near it," the reason being that we are simply thinning down the dielectric. The thin-walled elastic medium takes much less force to distend it than would the thick mass of dielectric reaching from the body to the walls or floor of the room. By approaching the body with an electrode connected to the earth by means of a chain, we do this; and when the ball of the electrode has been brought near enough, the strain in the dielectric has become so great that it breaks down, a disruptive discharge ensues, accompanied by a spark.

In fact, we have converted static into kinetic or current electricity, having electrolytic heating and other effects of a true current. But it is oscillatory in character; the rapidity of this oscillation is very great, and may reach as high as a hundred million vibrations per second.

We have arrived now at a point of the greatest importance to the electro-therapeutist, and that which requires most careful consideration. We have seen that the insulated body in connection with the machine is virtually the inner coating of the Leyden jar, the outer coating being represented by the electrode in the hands of the operator; the dielectric between them—as we have had frequent occasion to mention—is in a condition of strain. The force producing the strain is a "stress," or, as it is sometimes called, the electric tension; at the point opposite the ball of the electrode there is a tendency to stretch this part of the body outward, as it were, to tear off part of the surface. When the spark occurs there is a quick forward movement of the electricity away from the body, with an equally rapid recoil. The duration of the whole spark has been estimated to be all over in the hundred thousandth of a second. If we view the human body as a conductor, such a current would, I am afraid, penetrate to no appreciable depth. But experience tells us that a static-spark current does penetrate. To my mind, we must get rid altogether of the idea of thinking of the human body as a conductor in the same sense that we speak of metal as being a conductor. It conducts electricity, it is true; but it conducts it very badly. Nearly all bodies will conduct electricity more or less; but my contention is, that the human body is made up of conductors and insulators, or dielectrics; the skin with all the transparent tissues are dielectrics, the fluids being conductors. Now, this is just the combination that we require to transmit the spark current; and the electricity that resides upon the surface of conductors, as it were, soaks in here. If an insulated conductor be placed in a polarized dielectric between a charged conductor and the other conductor be an earth-plate facing it, and a constant difference of potential be maintained between them, the electricity in the dielectric acts inductively on the conductor, inducing a negative charge on the near side and a positive charge on the far side; the electricity has, as it were, slipped through the conductor, and the insulating medium has to bear a greater strain, though the electro-motive force is the same and the charge is increased.

If the dielectric were supposed to be stratified, each stratum of such dielectric, being strained, pushed forward like an elastic partition by the electricity trying, as it were, to get to the conductor whose potential is lower, then, if one of these strata gave way, there would be some further forward movement of the electricity, but the strain would have to be borne by fewer strata; the strain, therefore, on those remaining would be greater. By placing a conductor in a polarized dielectric we replace one or more of such strata. The human body, as I have said, is a very bad

conductor of electricity; this is common knowledge to us all in death from lightning. We know that it makes little difference what metal we use for a lightning-conductor, as the electricity slips along on the extreme outer skin, and does not penetrate sufficiently to find out whether the conductor be silver, copper, or iron. With Faraday's conducting-tube experiment before us, I think we must be compelled to view the human organism as made up of dielectrics and conductors; I do not see any reason to depart from the former statement I have made—though now dealing with organic matter—that insulators are transparent bodies, and conductors are opaque. The skin I consider a dielectric,—I do not say a perfect dielectric; there may be strata that slip more or less like the conductor in a polarized dielectric, though I should say that none of them slip so much; there is, however, a likelihood of differences in bearing strain. Static electricity having penetrated far, there may be next some fluids that allow a complete slip, electrolytic action being the means of conveying the electricity to the next dielectric (some transparent tissue,—sheaths of nerves, forms of fibrous tissue, etc.), which entangles the electricity and takes up the condition of strain, and so on. All this, let it be remembered, is due to static electricity alone, the body being charged from the prime conductor of the machine. It is hard to conceive, without such an explanation, what possible benefit is to be derived from static insulation alone (electric bath, or the souffle (electric wind); but I, for one, have not the slightest doubt of the excellent effects derived from the two latter applications of static electricity, independent of all suggestion or expectant attention. Now let us see what occurs at the moment of discharge. The electricity is straining the dielectric, both inside and outside the patient's body. Of course, the air part of this strain is the more perfect, as there are fewer slipping strata; in the dielectric within the body, however, there may be a good deal of this, causing a certain amount of leakage; so that the air strata have to bear the greater part of the strain. At the moment of discharge the elastic partitions or strata are broken down, the electricity is released—it surges forward—and as rapidly recoils backward. An obvious fact is that when the distorting force is removed the medium will spring back to its old position, overshoot it on the other side, spring back again, and thus continue oscillating till the original energy is rubbed away by viscosity or internal friction. Now released, there is no dielectric to restrain it; it is a true current, but an oscillating one.

MACHINES.

We have seen, first, that bodies may be electrified by friction; secondly, by induction or proximity to an electrified body; thirdly, that electrified bodies not only attract non-electrified bodies, but communicate electricity to them by contact; and, fourthly, that bodies similarly electrified, either by each other or from the same source, show mutual repulsion. These principles underlie the construction of all electrical

machines. The simple plate-glass machine consists of a large disc or plate of glass revolving on a horizontal axis, the axis of the plate passing through wooden supports, and the handle which turns the machine is made of glass; as the glass plate revolves it is rubbed against by two sets of rubbers, one above and the other below; at an angle of ninety degrees from each of these rubbers there is fixed a bent brass rod, surrounding but not touching the edge of the plate, and furnished on the side presented toward the plate with small, projecting spikes; these two brass rods are attached to the ends of a thick brass conductor, supported on

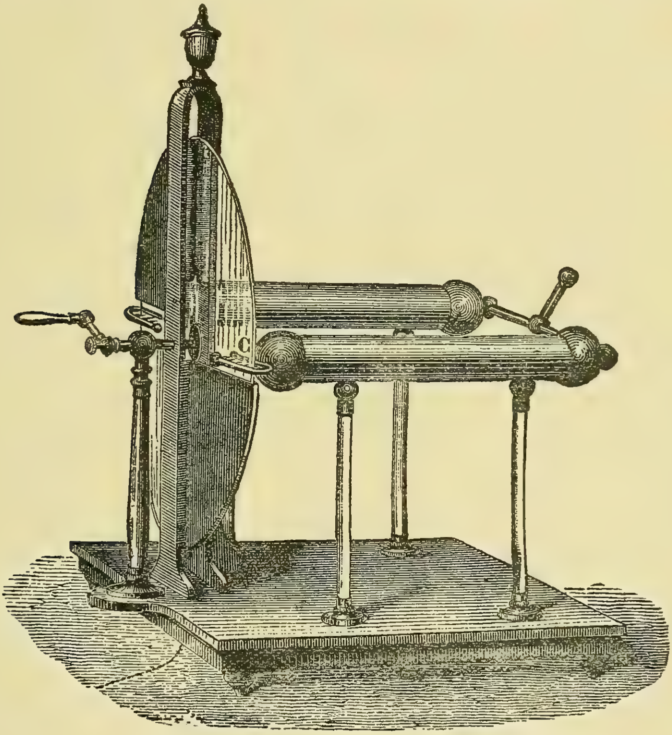

FIG. 1.—ONE FORM OF PLATE-GLASS MACHINE (THE RUMSDEN).

an insulating stand, usually made of glass. This is known as the prime conductor; it need not have any special form, except that every part of it must be rounded, with the exception of that presented toward the glass plate, as we have seen that the electricity of a conductor always distributes itself entirely on the surface of such conductor, and in such a manner that the accumulation of electricity is always greater at the most pointed parts, and least at the most rounded. As we have seen that the electricity upon any conductor tends to drive away the electricity upon another conductor in the neighborhood, so, in like manner, the electricity on a conductor behaves to the electricity on the same conductor. At

every point of a conductor there is a force acting outward from it which tends to break down the insulation of the air or other dielectric surrounding the conductor, and to cause the escape of the charge. This force is greatest where the accumulation is greatest,—at the most pointed parts, in other words. It follows, therefore, that the conductor should be round—having no points or edges—except opposite the glass disc; for here we wish to facilitate the flow of electricity between the conductor and the glass. Before using the machine a little amalgam of mercury and tin rubbed up with some tallow is smeared over the rubbers, as this is found to promote the transfer of the electricity. When the handle is turned and the glass plate revolves, it becomes electrified positively by friction against the rubbers. The rubbers at the same time become negatively electrified, which electricity flows to the earth; or, as far as our knowledge goes, we may say, with equal reason, that the rubbers lose positive electricity, and, to supply this, more positive electricity flows up from the earth to the rubbers, and the rubbers are connected to the earth. As the plate turns around, the positive electricity is brought opposite to the points. The positive electricity on the plate, as the latter passes between the points, drives the positive electricity of the prime conductor to the farther part, and therefore leaves the points and that portion of the prime conductor in their neighborhood with a deficiency of positive electricity, or, as we may say, electrifies them negatively. There will therefore be a force acting upon the electricity on the points, tending to drive the negative electricity outward from the points toward the glass, or, in other words, tending to draw positive electricity away from the glass plate on to the points of the conductor. The part of the glass plate opposite the points thus loses the greater portion of its charge. In passing through the second pair of rubbers, it again becomes charged as before; this charge is delivered up to the second set of points. This process continues until the potential of the conductor is so nearly equal to the potential of the plate that the force between them becomes too small to cause any further transfer of electricity. If, however, some outlet be provided for the electricity which accumulates upon the prime conductor, the action may be continued indefinitely. This is the simplest form of electrical machine, but is seldom used in medicine.

At the present time influence or induction machines are very generally used by electro-therapeutists. Before studying their action, it would be as well to give a short description of an "electrophorus." This simple instrument was invented by Volta, in 1775, for obtaining a series of charges of electricity from a single charge. It consists of (1) a generating plate,—a flat, round cake of resin, sealing-wax, shellac, or vulcanite contained within a metal dish or resting upon a metal plate; (2) this metallic plate or dish is called the "sole"; (3) a disc of metal of slightly smaller diameter, having attached in the centre an insulating handle, which is called the cover or collecting plate. The method of charging is

as follows : We warm the generating plate until it is quite dry, then rub it with flannel or strike it with a fox's brush ; this makes negative electricity manifest on the upper surface of the cake ; now, as we know, the cake is a dielectric, and the layers or strata composing it are in a state of strain, consequent on the charge it has received ; it induces positive electricity on the upper part of the sole, and, as the cake is uninsulated, the negative electricity escapes to the earth, or, as we might say, a positive charge comes from the earth. So the plate has a positive charge of electricity and the cake a negative charge. Place the cover, by means of the insulating handle, on the generating plate ; the two discs do not touch intimately, for there is an air-film between them ; we have therefore a negatively-charged body separated from a conductor. The consequence is that induction takes place,—a positive charge attracted to the lower side of the disc, a negative charge repelled to the upper surface. If the cover is touched with the finger, the free negative electricity escapes through the body to the earth, or we may regard it as being neutralized by positive electricity flowing from the earth through the body and hand. Remove the finger, and the positive charge on the cover is, as it is said, "bound" by the negatively-charged plate. The cover is then lifted by the insulating handle, and is found to possess a charge of positive electricity sufficiently strong to yield sparks when the knuckle is presented to it. If the generating plate be perfectly dry, this may be repeated many times from the same charge given to the cake. These series of events go on rapidly and continuously in all influence or induction machines. Suppose we have an insulated, uncharged conducting vessel or shell, B, and a positively-electrified conductor, A, insulated, and we introduce A into B, not touching the side, the interior surface of B will be charged by induction with a quantity of negative electricity equal to the quantity of positive electricity on A; at the same time the exterior surface of B will be charged with an equal quantity of positive electricity. The position of A inside B will not affect the amount of these charges. It will affect the distribution on the inner surface of B, but on the exterior surface of B the distribution will be unaffected by the position of A, being determined by the form and position of the walls and floor of the room where the experiment is performed ; changing the position of A inside B will not affect the potential of B. If A be allowed to touch B, the opposite charges upon their opposed surfaces cancel each other, leaving B wholly charged with a quantity of positive electricity equal to that originally on A. If A be now withdrawn, recharged with positive electricity and introduced inside B without touching, it will induce a new negative charge on the interior of B ; a new positive charge will now be added to that already on the outside of B. If A now touches B, the opposed charges on the opposed surfaces will again cancel each other, leaving two positive charges on the exterior of B ; this process can be repeated any number of times, so that we can give B an indefinite num-

ber of charges. When A is wholly inside B each charge added raises the potential of B, which may be raised in this way indefinitely above that to which A is charged by the source of electricity. In bringing A toward B while both bodies are charged, say, positively, we work to overcome their repulsion, and by the time A has passed inside B there has been sufficient work done to raise the potential of A above that of B; though A when it received its charge was at a much lower potential than B. We see that a charged body introduced inside a conducting shell, and then brought into contact with it, gives up its charge wholly to the shell, no matter what the relative potentials of the two conductors may have been before the one was brought inside the other.

All induction or influence machines depend, for their actions, on the foregoing principle. If we take two such insulated shells, B and C, and give a slight charge of positive electricity to B; and now take an insulated brass ball and bring it near the conducting shell, B, but not touching it, the positive charge on B induces a negative charge on the side of the ball next it; we now touch the ball with the finger, and the effect is we withdraw the repelled positive charge, leaving the ball with a negative charge. Now place the ball inside the uncharged shell, C, and allow them to touch. As we have previously seen, the negative charge is entirely given up to the shell, C. If the ball be removed from C and held near the outside of C, a positive charge is induced on the side of the ball next C and a negative on the other side. Touch the ball with the finger and the negative charge is conveyed to earth, and we have the ball with a positive charge; this charge can be given up to B by placing the ball inside it and allowing it to touch, which increases the positive charge already on B. This increased charge on B is then used, in the same manner as the original one, to electrify the ball negatively, and, the charge on B being increased, the negative charge on the ball will be greater than before. This is given up to C in the same manner as before, and the increased negative charge on C is used to develop by induction an increased positive charge on the ball, which is transferred again to B. If we continue this process, the difference of potential between C and B may be so increased that if they are brought close together a spark will pass from one to the other. An influence machine simply consists of an arrangement for carrying on such a series of operations as has just been described in rapid succession.

A revolving carrier or series of carriers is used, together with an inductor or series of inductors, between which and the carrier a certain small difference of potential must be excited in order that the machine may start. The carriers as they pass the inductors are electrified by induction, and when passing out of the influence of the inductor they are touched by a spring in connection with a collector, which in its turn acts as an inductor, and in this way a very small difference of potential can be rapidly increased to a considerable extent. With the other forms of

influence machines it was necessary to begin by electrifying one of the conductors. Influence machines, however, are now made which are able to excite themselves without external assistance, by means of a small difference of potential which invariably exists between the inductors, and which is sufficient to begin the series of operations.

The lower part of Carré's dielectric machine, as seen in the cut, is a plate of glass supported on vulcanite pillars; in fact, is an ordinary plate-glass machine with only one set of rubbers, which are uninsulated; it is turned by the ordinary handle; above this and on supports, overlapping the glass disc in its upper half, is a larger disc of ebonite, which is made to revolve at the same time as the glass disc, but necessarily at much greater speed; both plates are surmounted by a large brass

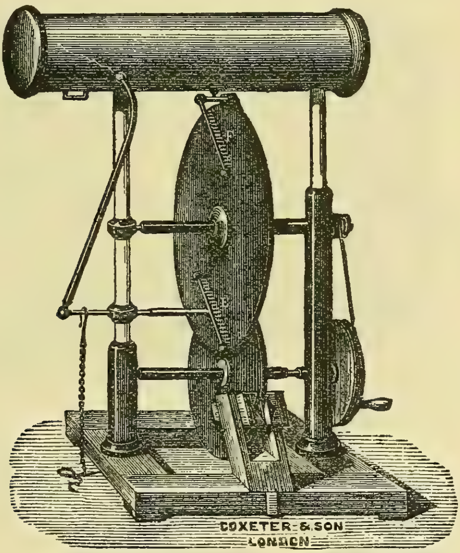

FIG. 2.—THE CARRÉ DIELECTRIC MACHINE.

cylinder,—the prime conductor,—from which projects a brass rod having a number of points for collecting the electricity from the ebonite plates. We thus see an illustration of the electrophorus, a quantity of electricity being supplied by the glass plate, but which is positive electricity of the same sign appearing on the side of the ebonite plate next the points; the upper set of points, *F*, taking up the positive electricity; the lower set, *E*, being connected to the earth by means of the chain.

This machine is made in three sizes, all of which produce a fair quantity of electricity. The second size is the one generally used by electro-therapeutists, the diameter of the ebonite plate being twenty-one inches, that of the glass fifteen inches. This machine, under favorable conditions, gives a spark of about ten inches. It is very reliable in most atmospheric conditions.

The Wimshurst influence machine consists of two circular discs of ordinary window-glass, mounted upon a fixed horizontal spindle in such a way as to be rotated in opposite directions, at a distance apart of not more than one-eighth of an inch. Each disc is attached to the end of a boss, of wood or ebonite, upon which is turned a small pulley. This is driven by a cord or belt from a large pulley, of which there are two, attached to a spindle below the machine, and which is rotated by a winch-windle, the difference in the directions of rotation being obtained by the crossing of one of the belts. Both discs are well varnished, and cemented to the outer surface of each are twelve or more radial, sector-shaped plates of thin brass, disposed around the discs at equal angular distances apart. The two sectors situated in the same diameter of each

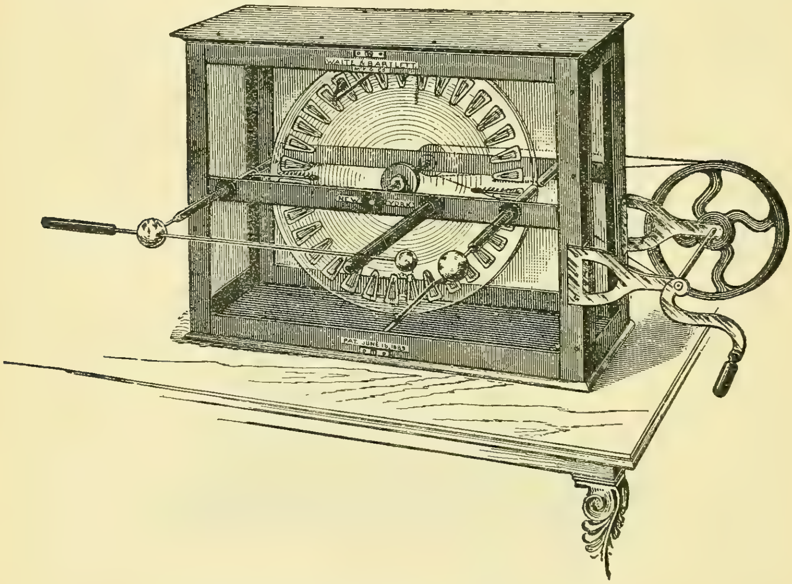

FIG. 3.—THE WIMSHURST INFLUENCE MACHINE.

disc are twice in each revolution momentarily placed in metallic connection with one another by a pair of fine-wire brushes attached to the ends of a curved rod, supported at the middle of its length by one of the projecting ends of the fixed spindle upon which the discs rotate, the brass sector-shaped plates just grazing the tips of the brushes as they pass them. The position of the two pairs of brushes with reference to the fixed collecting combs, and to one another, is variable, as each pair is capable of being rotated on the spindle through a certain angular distance; and there is, as in the case of the collecting commutator brushes of dynamo-electric machines, one position of maximum efficiency. In this machine it appears to be when the brushes touch the discs on diameters situate about forty-five degrees from the collecting combs and

ninety degrees from one another. The fixed conductors consist of two forks furnished with collecting combs directed toward one another and toward the two discs which rotate between them, the position of the two forks, which are supported on ebonite pillars, being along the horizontal diameter of the discs. To these collecting combs are attached the terminal electrodes, whose distance apart can be varied by the two projecting ebonite handles shown in the illustration. These collecting combs appear merely to convey the electric charge to what may be called the external circuit, for the induction action of the machine is as rapid and powerful if both are removed and nothing left but the discs and brushes; when in the dark, the machine being worked, the whole apparatus bristles with luminous electricity. The machine is, moreover, self-exciting, requiring neither friction nor the spark from any outside electric exciter to start it.

An extract from *Nature*, May 3, 1883, says: "It appears that in this machine the metal strips affixed to the plates act both as inductors and carriers. Suppose the front plate be rotating clockwise and the back plate counter-clockwise. If the metal strips descending from the summit on the left on the back disc are charged positively, the metal strips ascending on the front disc from the left will, as they pass under the momentary touch of the brush, acquire a negative charge. As these negatively-charged strips of the front plate advance toward the right, they will come to a point where they are opposite to the upper end of the hinder diagonal conductor, and here, whilst still acting as carriers to bring the negative charge round to the right side, they will act as inductors, and will influence the strips of the back disc, which will, as they are in turn touched by the hinder brush, acquire positive charges. The strips on the front disc will therefore constantly carry a negative charge as they move over the top from left to right, and those of the back disc will carry a positive charge from right to left. In the lower halves of their respective rotations the inverse of these actions will hold good, the front carriers conveying positive charges from right to left, the back ones conveying negative charges from left to right. The result will, of course, be that the two main conductors on the left and right will become, respectively, positively and negatively charged. If dry and free from dust the machine excites itself, and, after a couple of turns have been given to the handle, discharges sparks freely. If the two main conductors are respectively joined to the inner and outer coatings of a large Leyden jar, the discharges take place with short, loud sparks of great brilliancy. If from any cause the maçhine does not at once charge itself, gently rub with a silk handkerchief either of the ebonite pillars."

Professor Lewandowski claims that his machine, differing in its construction from all hitherto-known influence machines, answers the therapeutist's purpose better than any other; the merits claimed for it being that it is uninfluenced by moisture and temperature, as the generating

part of the machine is inclosed in a cylinder. The following figure represents the machine, and the principle of this contrivance consists in the employment of two hollow drums of idio-electric bodies, of which one is somewhat smaller than the other and is shut up perfectly air-tight within the others; both rotate round the same axis, though in different directions. The two vertical iron supports, $a\,a_1$ and $b\,b_1$, are screwed to the

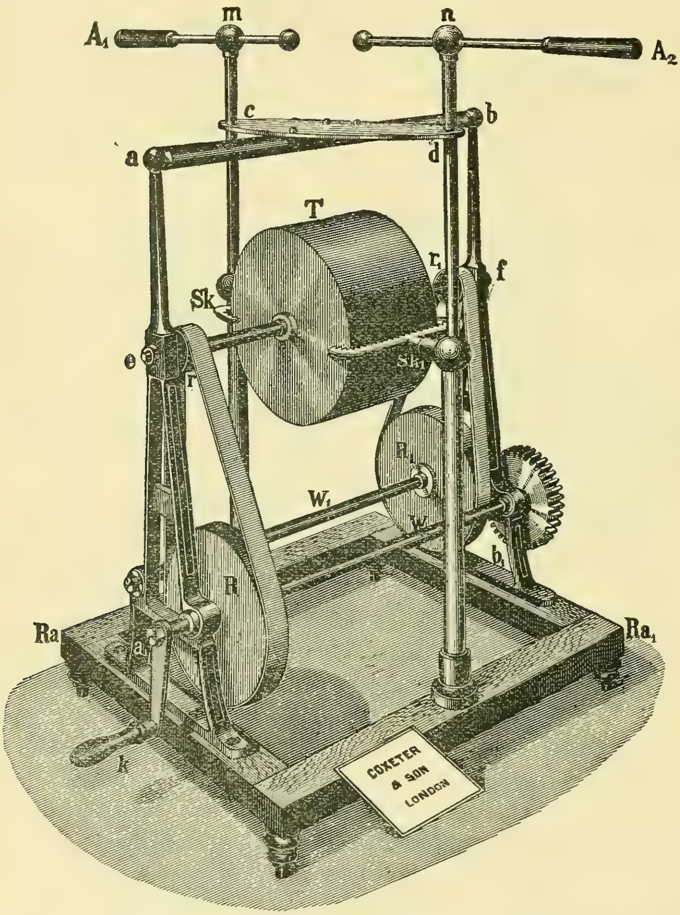

FIG. 4.—PROFESSOR LEWANDOWSKI'S MACHINE.

rectangular wooden frame *Ra* and Ra_1, seventy by fifty centimetres, their tops being joined together by the vulcanite rod, *a b*. These two uprights support the axles, *e f*, *W*, and W_1, which are parallel to each other. The axle, *e f*, is fixed and made of steel. Upon the chief axle, *e f*, there are two vulcanite collars, one of which is joined to the pulley, *r*, and the other to the pulley, r_1. In the middle of the two collars there are, on the chief axle, two hard-gum cylinders, one within the other, *T*, T_1 (Fig. 5).

The pulley r is connected with the internal cylinder, T_1; whereas the pulley r_1 is connected with the external cylinder, T; so that the internal cylinder and the external one can be rotated quite independently. The two lower axles, W and W_1, each carry a large pulley, R and R_1, and a toothed wheel; the large pulleys, R and R_1, are respectively united by means of straps to the superior pulleys, r and r_1. The axle, W, moreover, carries the handle, k. This whole arrangement allows the two cylinders to be turned in the reversed direction, when the handle rotates only in one direction. The wooden frame carries, besides, two uprights, the lower parts of which are made of glass and the upper of metal; they terminate in the metallic knobs, m and n. In the middle of these supports are two metallic knobs, Sk and Sk_1, each carrying a collecting comb in close proximity to the external cylinder; whilst one metal double comb, sk sk_1, inclosed in the small cylinder, is carried by the fixed axle, e f. In the balls m and n are the conductors, A_1 and A_2,

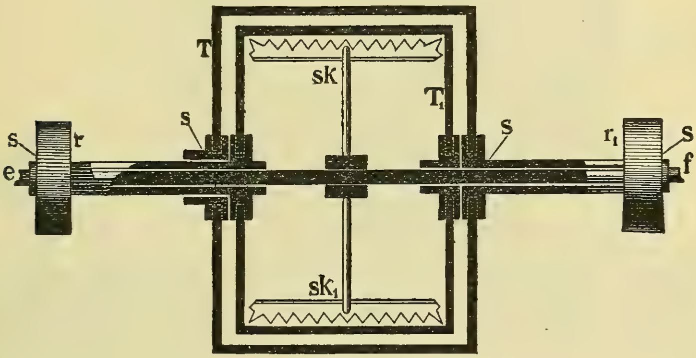

FIG. 5.

which can be moved to and fro horizontally. The turning of the handle, k, brings about the rotation of the outer cylinder, T, through the transmission of movement by means of the pulleys R and r; whilst at the same time, in consequence of the turning of the toothed wheel, the axle W_1 rotates in an opposite direction, and this motion carries the small cylinder, T_1, over by means of the pulleys R_1 and r_1. If the knobs of the conductors are brought near each other so as to come into contact, when the handle is turned in any direction it suffices to touch the surface of the external cylinder with a piece of hard caoutchouc, which has been slightly rubbed on the clothes, either above or below the middle of the drum (corresponding with the middle of the inner vertical double comb). This exciting or charging of the machine is manifested by a whizzing sound. If the motion be stopped, the electric charge of the cylinders lasts for several hours. If the handle be turned in the opposite direction, the machine does not become uncharged.

Atkinson's Toepler electric machine is an electro-static machine, of

high tension and large quantity, whose sensitiveness to atmospheric influences does not interfere with its practical working. It is made with two circular plates of glass, one stationary, the other revolving close in front of it; two sets of combs and two Leyden jars, with a switch between them. To the back of the stationary plate are attached two sets of paper and tin-foil *inductors*, connected with which are two wire brushes, and to the front of the revolving plate are attached six metal *carriers* with

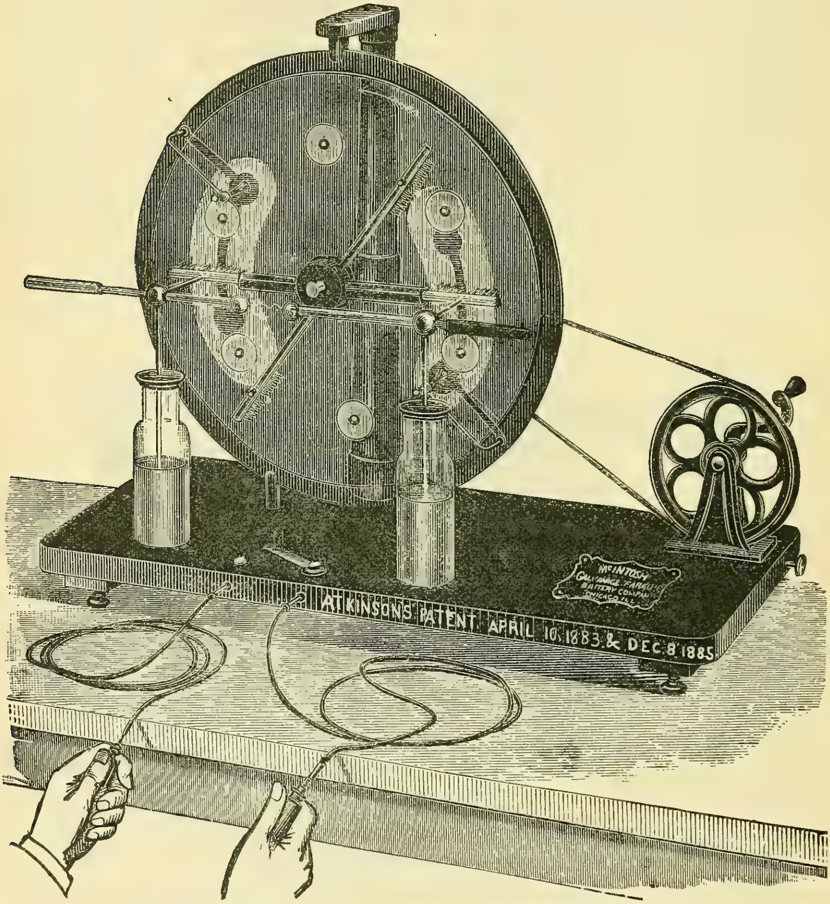

FIG. 6.—ATKINSON'S TOEPLER ELECTRIC MACHINE.

raised centres, which are brought into contact with the brushes as the plate revolves, and generate the electric charge, which is rapidly increased by induction. Opposite parts of the plates and opposite inductors and carriers become oppositely electrified, condensation takes place in the jars, and sparks pass between the sliding electrodes, which may be increased to seven inches or more in length. Electricity is generated at once, and the electric charge constantly sustained by the friction of the carriers

and brushes; hence the machine remains in practical working-order under the most unfavorable atmospheric conditions.

The switch, as seen in the cut, is placed between the Leyden jars, and in connection with their outer coatings, so that the induced current between them is controlled by the operator. As this current flows at the same instant with the discharge between the sliding electrodes

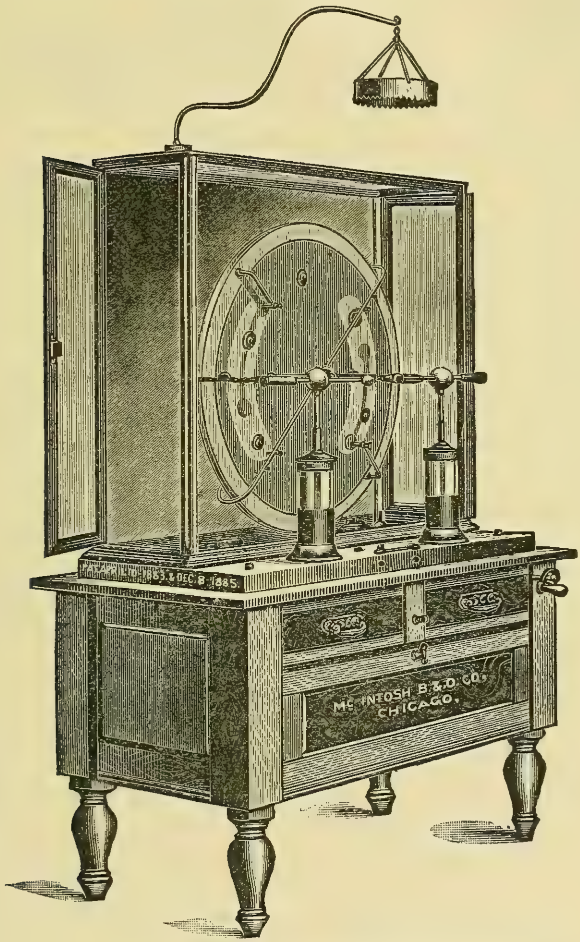

FIG. 7.—ATKINSON'S TOEPLER ELECTRIC MACHINE.

connected with the inner coatings, it is only necessary to separate them to obtain the interrupted induced current similar to the faradic. In connection with the switch are seen cable cords and electrodes, which may be held by insulating handles and applied to any part of the body. Opening the switch changes the current to the cords and electrodes, and on separating the sliding electrodes the faradic effect is at once produced, which may be varied from the slightest tremor to the most violent mus-

cular twitchings. A separation of one-sixteenth of an inch produces a mild, pleasant sensation; one-eighth to one-fourth of an inch becomes painful; while a separation of one-half to three-fourths of an inch can hardly be borne by the strongest nerves. When the switch is closed and the sliding electrodes drawn out beyond sparking distance, a person seated on an insulated platform and connected by cable-cord with the ball surmounting the Leyden jar farthest from the driving-wheel will receive a condensed charge of positive electricity, or of negative if connected with the jar nearest the driving-wheel.

In damp, warm weather, a film of moisture sometimes settles on the glass plates and temporarily suspends insulation, so that the machine ceases to generate. The effectual remedy in such a case is to dry and warm the plates, which may easily be done in a few minutes by placing one or more kerosene-lamps near them. The warming is as important as the drying, to prevent further deposition of moisture on the surface.

The Franklinic Interrupted Current and Static Induction.

A very important advance in the application of static electricity was made by Dr. Morton, of New York, in 1881. This was the introduction of what he terms the franklinic interrupted and the static induced currents. As we have seen, in drawing a spark from the patient on the insulated platform, we break down the dielectric between the metal ball and his body and, by doing so, cause a real current of electricity to pass, and close the circuit. The two coatings of the Leyden jar have been connected. The patient's body is brought in contact with the earth by means of the chain on the electrode, and, as one pole of the machine is earth connected, the circuit is thus completed. At the same time, we must remember that the current we have produced is an alternating one. In this case the patient receives the spark, the circuit being broken at the patient's body. But we could quite conceive that the circuit might be broken at any part of it,—say, a foot from the patient's body,—he himself holding a piece of brass rod or other conductor having an insulating sheath, the ends of the rod terminating in two brass balls, and one end of this rod applied directly to any part of the body to be acted on. If we now, instead of drawing a spark directly from the body, draw it from the external brass ball, the disruption takes place then between the external end of the conductor held in the patient's hand and the ball of the electrode in the operator's hand. At the moment of the occurrence of the spark the patient receives the rapidly-alternating current through the electrode held in his hand. The current might be broken at any part of the circuit, and the patient as part of the circuit feeling the effects. Dr. Morton has constructed an electrode for application of the franklinic interrupted current. It breaks the circuit at some distance from the patient's body; the end next the body may be a moist

sponge or other terminal, such as is used in applying the faradic current. There are two brass balls which constitute the circuit-breaker; these can be separated and brought together by a movement of the operator's finger. The spark passes between them and can be regulated by the distance between the balls.

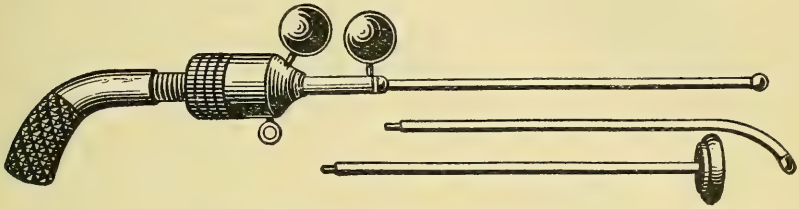

FIG. 8.—MORTON'S ELECTRODE.

STATIC INDUCED CURRENT.

Dr. Morton says: "For this current the electrodes and conducting cords must be especially constructed; the metal within the sponge of a plate should be rolled back upon itself at its edges, so as to present a rounded peripheral contour, or, better still, it should be a ball of about an inch in diameter; the handles of the electrodes should be long and made of ebonite; the conducting cord should consist of a thick strand of fine wire well insulated by gutta-percha. These precautions are necessary, owing to the great 'tension' of the current, and its consequent disposition to break down insulating barriers, which in the case of ordinary currents would suffice to confine them to their proper conductors. To use the current, bring the discharging rods of the machine into contact. If the Holtz machine, remove the connecting rods which *unite* the

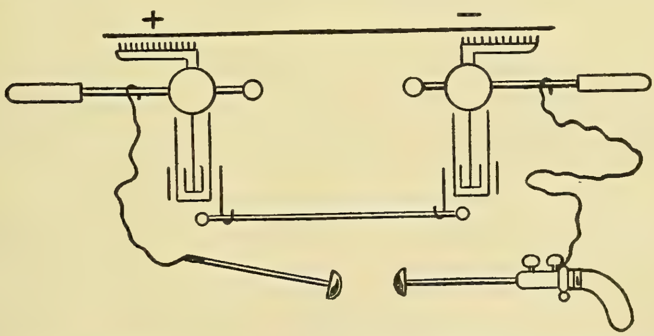

FIG. 9.—DIAGRAM ILLUSTRATING CONNECTIONS FOR INTERNAL TREATMENT BY THE STATIC UNIVERSAL ELECTRODE.

two Leyden jars and hook on the two conducting cords and electrodes. The patient need not be insulated. If now the wet electrodes be grasped, the machine set in motion, and the discharging rods separated a very small fraction of an inch, the current will be felt, and may be graduated to any strength desired or bearable, and may be localized in its applica-

tion, internally and externally. In the machine of Carré jars of about eight ounces in capacity are used, and are simply suspended from each conductor by means of a hook; to the outer coating of the jars are attached the conducting cords with the moist electrodes; the poles in this machine may be separated for about an inch. The strength of the current is determined by the size of the jars and amount of separation of the poles. Nerve and muscle may be acted on in exactly the same way as in the application of faradism, but, to my mind, in a much more effectual and less painful manner. I have seen muscles react to this current when not the slightest reaction could be obtained from the strongest bearable application of faradism, using both coarse and fine coil. This form of electricity, by means of special electrodes, can be used for the vagina, uterus, or other internal canal or cavity (as shown in diagram)."

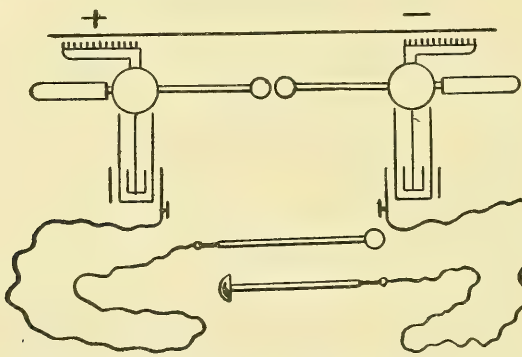

FIG. 10.—DIAGRAM ILLUSTRATING STATIC INDUCED CURRENT, WITH ELECTRODES FOR INTERNAL TREATMENT.

CHOICE OF MACHINE AND METHODS OF APPLICATION.

In the application of static electricity in electro-therapeutics the first consideration presenting itself is the choice of a machine. Almost all the types in use at the present time are good. De Vigourout, of Paris, whose experience of static electricity has been very great, speaks most highly of the Wimshurst machine and that of Carré. The Holtz machine appeared to him to give too much electricity and to have too exciting an effect upon certain patients. He says, "We must not attach too much importance to these questions of apparatus, but I will say there is an advantage in using large machines. The discs of the Wimshurst at the Salpêtrière are seventy centimetres, and I have actually tried one of one metre. It seems impossible to obtain good effects from small machines, which cannot be used without a condenser, and which patients are ordered to buy, with the injunction (too common an error) to treat themselves." My own experience would correspond closely to this. The main object is to get a machine that you can rely on in all atmospheric

conditions, giving a fair quantity of electricity at a sufficiently high pressure or potential.

METHODS OF APPLICATION.

1. *The Electric Bath, or Static Insulation.*—The patient is placed on the insulated platform, in communication with one of the poles of the machine,—say, the positive. After some turns of the handle he is found to be charged with positive electricity of a high potentiality, at the same time offering means of a constant waste of electricity from all parts of his body and clothes,—waste which is continually repaired by the electricity flowing from the conductor of the machine. The physiological and therapeutical effects of the electric bath cannot be doubted. This is the base of all treatment by static electricity, and might even constitute it entirely; after at least a few sittings its action is purely sedative.

2. *The Electric Souffle, or Wind.*—This is obtained by directing the point of a metallic, uninsulated rod toward the patient, at a distance of about a foot, by induction; the point is electrified negatively (that is, if we are using positive electricity); it communicates its electricity to the adjacent air-molecules or dust-particles; they are thus attracted to the nearest part of the patient's body, and we have a discharge by convection, by a stream of particles producing an actual current in the air. The action of the souffle as a sedative is most remarkable, and may be compared with the galvanic anode, but it is found to be more energetic.

3. *Sparks.*—These are obtained by bringing a metal-ball electrode sufficiently near the patient that the dielectric between the ball and the body is broken down; they are used to excite muscular contraction by acting on the muscle direct, or on the nerves supplying the muscles, and to excite cutaneous sensibility.

4. *Aigrette.*—This is produced by bringing a rather blunt metal point or a piece of wood near the patient's body. We have no electric wind or spark, but an intermediate form of discharge. When the point is positive it is a luminous brush of a bluish or violet color. This form of application is especially useful in the treatment of nervous patients, where we wish to lead up to stronger applications, or where we want to act upon a sensitive surface, as the face.

5. *Electric Current.*—This is effected by passing a metallic, uninsulated ball more or less rapidly over the patient's clothing. It thus produces a multitude of little sparks, whose length is measured by the thickness of the interposed fabrics. The friction brings about a disagreeable or even a painful sensation,—smarting and burning. The skin is reddened as by stinging. Some patients whose cutaneous sensibility is dull or perverted find the friction agreeable. The reason why the friction can only be made over clothing is evident; if the ball were applied to the skin there would be no insulation, as it simply conveys the electricity to the earth; the friction, like the sparks, exercises a stimulating local action and a distant and reflex action, whose effect, on the whole, is sedative; practiced over a large surface of the body, it is distinctly stimulating. Friction made on the lower half of the body diminishes spinal congestion, such as a spasmodic state of the lower limbs, exaggerated reflexes, seminal emissions, etc. During the action of an electrical machine ozone, or distinctly odorous gas, is developed in considerable quantities. The peculiar smell which accompanies a flash of lightning is due to the transformation of atmospheric oxygen into this gas. According to Dr. Lauder Brunton the passage of an electric spark causes the molecule of oxygen to split up into single atoms, which do not, however, remain apart, but immediately coalesce either with other single atoms to re-form molecules of oxygen or with other molecules of oxygen containing two atoms to form a molecule of ozone, which thus contains three atoms. To show the presence of ozone a piece of paper impregnated with a solution of iodide of potassium is used; if the gas is present the paper will assume a deep-blue color. This gas can be administered in an effectual manner to the patient by means of an insulated electrode consisting of a small disc carrying half a dozen points. The electrode is held near the patient's open mouth (not within sparking distance), and he is required to breathe deeply, thus inhaling the ozone. This is of great service in asthma and anæmia.

COMPARISON BETWEEN GALVANIC AND STATIC ELECTRICITY.

If we take an ordinary galvanic battery—say, of 20 cells—and complete the circuit by means of a piece of fine platinum wire a few inches in length, it is raised to a white heat. If we complete the circuit in an induction machine by joining the poles by means of the same wire, no effect whatever will be observed. In the latter case the quantity of electricity is too small to sensibly heat the wire. If the terminals of a galvanic battery be two copper wires and the circuit completed by bringing them together, a small spark will be seen when they touch, but the spark is so short that it would be impossible to measure it, while with an electric machine of moderate size we would get a spark of several inches in length. If we connect a Leyden jar by its two coatings to the poles of an electrical machine and the handle is turned for some time, the jar will either burst or overflow, if the machine is powerful enough: if not, a strong spark will be obtained by connecting its inner and outer coatings. If the ends of the wires from the battery be now connected to the coatings of the jar, it will be found that, however long the battery may be left on, neither overflow nor spark will be produced. To charge a Leyden jar we require not a large quantity of electricity, but a high potential difference. The electrical machine gives a high potential difference, but a very small current; at the same time be it remembered that static electricity can do all that can be done by galvanic or dynamic electricity; it has physiological as well as luminous and heating effects; it can magnetize iron or steel and produce chemical changes. It is not improbable that before long a static machine may be invented not only giving a high voltage, but a large quantity of electricity; the problem to be solved is the lessening of resistance between the different parts of the machine.

MAGNETISM.

An ordinary bar magnet exhibits certain familiar phenomena when suspended by its centre of gravity; though free to turn in any direction, it will invariably come to rest in one position,—that is, with its poles or ends pointing north and south. The forces which turn the magnet into this position, or maintain it there, are due to the action of some other body, which may be a magnet. The space where a magnet experiences this action is called a *magnetic field.* The earth produces a magnetic field. The forces experienced by a magnet and due to the earth's magnetic field are sensibly the same at all parts of any space of moderate dimensions, as a room. Within such a space the field is said to be *uniform*, and the direction of the magnetic force is the direction which the axis of a freely-suspended magnet would assume. When the axis of the magnet does not coincide with that direction, two equal and opposite parallel forces act on the magnet; these forces tend to turn the

magnet so as to bring the axis into the direction of the magnetic force. The body producing the magnetic field experiences equal and opposite forces, tending to turn it in the opposite direction. A magnet produces a magnetic field in its neighborhood and modifies any magnetic field previously existing there. The field due to a magnet is not uniform; the forces may be much greater than those due to the earth. Magnetic fields are also produced by electricity in motion. Under the undisturbed action of the earth's magnetic field the end of the axis of any magnet points in a direction which differs at different parts of the earth's surface, but which is always northerly. If a magnet be broken into the smallest particles possible, it will be found that each particle is a magnet having two opposite poles, so that each particle possesses properties exactly similar to a bar magnet. We may imagine a magnet to be composed of molecules which cannot be further divided by physical means. This include's Webber's theory. Ampère's theory, which is now generally accepted, supposes that each molecule of the magnet has a current of electricity circulating round it. These currents are assumed to exist in all magnetic substances; before magnetization they move irregularly; after magnetization they circulate in parallel directions. If the observer face the north pole of the magnet, the currents move in an opposite direction to the hands of a watch, and, of course, looked at from the south pole, they move in the same direction as the hands of a watch. So we see that magnetism can be defined as electricity in rotatory or whirling motion.

An electro-magnet is simply a bar of soft iron, generally in the shape of a horseshoe, round which a coil of insulated wire is wound, through which a current of electricity can be passed. Electro-magnets are often used to magnetize bars of steel, as they are much more powerful than ordinary permanent magnets. We can magnetize by an electric current in the following manner: By winding silk-covered copper wire in a coil, attaching the ends to the terminals of a fairly strong Voltaic battery; move the coil from one end to the other of a bar (or a horseshoe-shaped piece) of steel, taking care to move it always in one direction. We can also magnetize by the earth's induction. If we take a poker and hold it parallel to the direction of a freely-suspended magnetic needle, we should expect that, if the poker were built up of magnetic molecules, each molecule would try to set itself in a direction parallel to the suspended needle; for we should suppose that the earth would act on the molecules of the poker as it does on the needle. The direction or dip of a suspended magnet at this part of the world is almost vertical. So we should hold the poker vertically. If we hold it thus for a few minutes and then test it for magnetism by trying whether either end of it has the power of repelling either end of a suspended magnet, it will be found that it has not acquired any sensible magnetic properties. Steel railings, however, which have remained in a vertical position for many years, have frequently been observed to have acquired magnetic properties, the lower

end having become a north pole, as we should expect, if Webber's theory be true. Now, as we know, all the molecules of the poker are closely packed together, and it is therefore quite possible that the earth may exert a force tending to set them in a definite direction, but that this may not be strong enough to overcome the cohesion of the molecules. If we could by some means diminish this cohesion, we might have better results; this can be done by simply striking the poker with a hammer when held in a vertical position, and it thus becomes a magnet, the lower extremity becoming a north pole; but if the poker be reversed and again struck its magnetism will be immediately reversed also. The cohesion of the molecules can also be diminished by heating the poker; when thus treated and left to cool in the vertical position, it becomes a magnet.

A slight sound is heard when a body is magnetized or diamagnetized by an electric current, and is due, according to this theory, to the sudden turning of the molecules. This production of sound during magnetization was utilized in one of the earlier forms of telephone receivers. Heat is also produced when a magnet is rapidly magnetized or diamagnetized.

We have seen that the space through which the influence of the magnet extends is the *magnetic field* of such a magnet. This force increases as we approach the poles and diminishes as we recede from them. At every point it has a definite intensity depending upon the distance from the poles; and it has a well-defined direction at every point, as indicated by the *line of force* passing through the point. We can see the general distribution of these lines of force by placing a sheet of cardboard above a magnet resting upon a table; if we sprinkle iron filings over the cardboard, and as the filings fall gently tap the cardboard, we can see that they arrange themselves along certain curves; these curves represent the lines of force.

Magnetic Induction.—A piece of iron, not of itself a magnet, will, when placed in a magnetic field, become magnetized in the lines of the magnetic force in the field. Thus a bar of iron, placed with its longest axis in the direction of the lines of magnetic force, will become a bar magnet, having its north pole at that end of the axis toward which a north pole would, under the influence of the field, tend to move.

The action by which iron becomes magnetic in a magnetic field is called *magnetic induction.* The molecules of iron in a magnetic body before magnetization are, by Webber's theory, assumed to have their axes turned in every possible direction, the magnetic actions of the molecules thus neutralizing each other so that the body will not act as a magnet. If the north pole of a bar magnet be brought near such a body it will attract the unlike poles of the molecules and will repel the like poles; so that the molecules will tend to arrange themselves with their north poles pointing one way and their south poles another way. The molecules will thus act together, forming a magnet whose south pole will be the pole next the north pole of the inducing magnet.

In a uniform magnetic field, iron magnetized by induction is not impelled in any direction by the magnetic force, which acts with equal and opposite force on the two induced poles. When the field is not uniform, the induced poles, which are themselves equal, are unequally acted upon, and motion tends to take place in the direction in which that pole would be urged which lies in the stronger part of the field. Thus iron, in virtue of the magnetism induced in it, is attracted by either pole of the bar magnet; for the end of a piece of iron, say, near a north pole will become a south pole and will be more attracted than the distant north pole of the iron is repelled. A magnet shaped like a horse-shoe having poles near the ends will attract a piece of soft iron placed opposite and across the ends to the best advantage, for each induced pole will be in the most intense part of the magnetic field which the magnet can produce.

We see here, as in static electricity, that induction precedes attraction. Iron in which magnetism has been induced can, in its turn, induce magnetism in another piece of iron.

Paramagnetism and Diamagnetism.—Other substances besides iron and steel can be magnetized by induction, acquiring properties similar to iron, but in a much feebler degree; these substances are called magnetic or paramagnetic to distinguish them from other substances, such as bismuth, which also acquire polarity under the influence of a magnetic field, but in which the direction of the induced magnetism is *opposite* to that of the magnetic force. The latter substances are called diamagnetic.

One result of these two opposite arrangements of induced poles is that all paramagnetic matter in a magnetic field tends to move from the place of smaller to the place of greater intensity of force, and that all diagnostic matter tends to move from the place of the stronger to the place of the weaker intensity of magnetic force. Diamagnetic matter is repelled, paramagnetic matter is attracted by the pole of a magnet; consequently, while a bar of iron, if free to turn, tends under the action of induction to place itself *along* the lines of magnetic force, a bar of diamagnetic matter, such as bismuth, tends to place itself across these lines. All bodies are either paramagnetic or diamagnetic, but the magnetic effects are much feebler with all known forms of matter than with iron or steel.

The Earth's Magnetism.—The earth's magnetic field is not one which could be produced by a simple bar magnet or any simple system of bar magnets. The earth has not got a magnetic pole in the sense given to the pole of the magnet. It is usual, however, to call these points on the earth's surface where the direction of the lines of magnetic force is vertical the magnetic poles. The magnetic pole situated near the northern end of the earth's axis resembles what we have called the south pole of a bar magnet; the earth's pole in the south resembles the north pole of a bar magnet.

Therapeutic Application of Magnets.—At the present time there is no evidence of a reliable nature that a magnetic field, no matter how powerful it may be, exerts any sensible influence on the healthy human organism. In certain abnormal states of the nervous system, notably in hysteria, effects of a remarkable character are produced; muscular contractions are relieved and anæsthesia temporarily cured when a large compound magnet is brought near the patient. This I have seen done at Charcot's clinic at the Salpêtrière, under the personal direction of Charcot himself. And there is no doubt that in other hands, as well as in his, they have been the means of even curing some neuroses.

At the Salpêtrière at the present time, however, magnets in the treatment of disease are little used, static electricity having almost entirely superseded them. In the use of magnets as therapeutic agents the phenomena are necessarily entirely of a subjective character, and are therefore open to many objections, amongst them being the possibility of such applications degenerating into charlatanry. Magnets are often of service in diagnosis, indicating the presence and position of needles or small pieces of steel or iron in the tissues, and are frequently a great aid in the removal of such foreign bodies. The electro-magnet is the form now generally used for such purposes.

THE FARADIC OR INDUCED CURRENT; ELECTRO-MAGNETISM; ELECTRO-MASSAGE, AND INSTRUMENTS.

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I. HISTORY.

The induced or interrupted current is generally termed the faradaic, or faradic, in commemoration of Faraday, to whom we owe the discovery of this form of electricity, and also the induction coil of Ruhmkorff, as a direct result of this discovery that an induced current of electricity is generated in a conducting, or closed, wire circuit placed *near to*, but *not in contact* with, another circuit through which a current is passing.

The history of faradic electricity, in its relation to medical science, is a curious and unusual one; hardly had it been discovered, three-score years ago, but its physiological and therapeutic properties were clearly defined; and it was not only at once accorded a place in medicine, but it attained a preponderance and popularity now unknown. Much has since been forgotten, and little has been added to our knowledge of this form of electricity, notwithstanding the wonderful progress in other branches of electrical and medical science.

In the early part of this century magneto-induction instruments of crude form were used here and there, but they proved unsatisfactory: the method of application was vague and general.

The first attempt at localized application, with a distinct object in view, was made by Sarlandière, in 1825, who sought to limit the effect of electricity to certain muscles and nerves by guiding the current directly to the part to be reached by means of needles, one connected with either pole, and plunged into the tissue so as to concentrate the current upon that part of the muscle or nerve between them. It is needless to say that the pain caused so far surpassed any possible benefit that this method found little favor.

Oerstedt, of Copenhagen; Ampère, Schweigger, and others led the way by their investigations to the development of this form of electricity, produced by the induction coil as invented by Faraday, who, moreover, in 1831 gave us the laws governing electro-motor induction, the induction of magnets on currents and of currents on currents, and showed that we can increase the electro-motor force by increasing the number of windings of the conducting wire, as each winding or turn of wire cuts across the lines of force independently. His electro-magnetic induction experiments, during the early thirties, led to the Ruhmkorff coil, which

has ever since served for the production of the faradic, induced, or interrupted current in the laboratory, and, without the condenser, as the type for all instruments employed in medicine.

Not one of the earlier instruments has survived, but we must record, as among the first, the apparatus for the therapeutic use of voltaic induction currents constructed in 1831 by Masson, and another invented about the same time by Pixon, for the application of magneto-electric currents.

It was not until the forties, after the investigations of Faraday and the invention of Ruhmkorff, that more serviceable magneto- and volta-electric instruments came into the hands of the practitioner so that this form of electricity could be practically utilized. At first the rotary or magneto-electric apparatus prevailed, but soon yielded to the more convenient volta- or galvano- electric instrument,—gradually disappearing more and more, until at the present day it is known by name only, notwithstanding some good points which should at least preserve it from total oblivion.

The new instrument soon became popular, as it was small, easily manipulated, and gave currents of great physiological energy; powerful effects upon the nerve were felt, and upon the muscle seen as well as felt, yet little was really accomplished; the current was vaguely and indiscriminately applied until Duchenne showed that it should be localized to attain satisfactory curative results. Others as well seized upon the new therapeutic agent,—men such as Marshall Hall and Golding Bird in England, Froriep in Germany, and others; but it was Duchenne, known by the city in which he labored as Duchenne of Boulogne, an accurate observer and careful experimenter, who, by his thorough electro-physiological and neuro-pathological researches, at once firmly established the induced current on a scientific basis; and we may well speak of this great apostle of faradism as the founder of modern electro-therapeutics. Enthusiast as he was, he practically excluded galvanism from the field by confining his work to this one form of electricity; and he not alone discovered its physiological and therapeutic properties, but developed and perfected them so that but little has been added since his day. As an able contemporary truly says, he placed faradism almost where it now stands,—far ahead of the present general knowledge. If we follow the course of his investigations, from his first publication in 1847 to the final results as they appeared in his classic work, "l'Electrisation Localisée," in 1855, we shall review the more important physical, physiological, and pathological features of faradic electricity.

Duchenne, guided by the idea suggested in the impracticable experiments of Sarlandière, sought to localize the current to certain parts or organs, to confine and concentrate its effects upon nerve and muscle without influencing the skin in its passage, or to concentrate its powers upon this superficial structure without affecting the underlying tissues.

He applied the dry metallic electrode to the dry skin, and, although sparks and crackling gave evidence to eye and ear of the passage of the current, as did the superficial sensory nerves, no physiological phenomena were produced, proving that it did not penetrate; the same current, applied to the same points by means of sponge-electrodes, well moistened in warm salt water, produced neither sparks nor crackling, but nerve-pain or muscle-contraction, as it traversed sensory or motor nerves or muscles. He also found that the muscle was contracted, not only by the current directly traversing its fibre, but also, and even more effectively, by a current penetrating at certain well-defined points, not necessarily near to or directly upon the muscle. These points—which he called "*points d'election*," points of choice—were proven, by Remak and von Ziemssen, to be the points at which the motor nerve is nearest the surface and most easily reached by the current, generally near where it enters the muscle. This discovery led him to make the distinction, still upheld, between *direct* muscular contraction, produced by placing an electrode upon the muscle itself, and *indirect* contraction, produced by irritation of the nerve controlling the muscle.

His thorough studies of the muscular system in health and disease were followed by physiological and pathological experiments upon other parts, and taught him, even then, the impotence, if not danger, of the faradic current in disease of the central nervous system.

Furthermore, it may surprise some of the prolific writers of the present day to know that Duchenne, as far back as the forties, recognized the difference between coils of heavy and of fine wire,—one of the most important features in faradic electricity,—which I have endeavored to elaborate, and which has called forth the attack, the sarcasm, and condemnation of certain of the authors of modern works on electro-therapeutics. Though Duchenne made the distinction between *primary* and *secondary* coils, finding that at times the current from the one, at times that from the other, appeared the stronger, he did not clearly understand that their individuality was due not to the difference in direction or induction in primary and secondary coils, but to their quality, the length and thickness of the wire forming the coil. He found that the action of the secondary coil was more intense upon the skin, and of the primary upon deep-lying organs, especially muscles, and speaks of an "electric" action of the coils, yet recognizes that the difference depends upon physical laws; although he himself could give no possible explanation of this clearly-established fact, he denies that given by the physicist Becquerel, who claimed that the varying tension of the coils must account for this difference in the effect of the current.

The discovery of the difference in the action of primary and secondary—in other words, of heavy and fine—coils was made by Duchenne in the faradization of the bladder with one electrode in the rectum and one in the bladder: finding some irritation of the sacral plexus in the use

of the secondary, or fine-wire, coil he desired to weaken the current, and inserted the primary, or heavy-wire, coil, which, contrary to his expectation, proved still stronger and caused intense suffering. Although unable to give an explanation, he clearly established the difference in the character of the current from primary and secondary coils, making five main points, to which I shall refer in the proper place.

Barring trifling errors, and the illusions of the enthusiast, as the man must be who would succeed in any one sphere, the work of Duchenne still stands, at the present day, as the foundation upon which every method of localized electrization is based, and, I can but repeat, strange as it may seem, far in advance of the present *general* knowledge.

The faradic current was received with general favor and overshadowed all other forms of electricity as a therapeutic agent; its preponderance being due to the thoroughness and the wide-spreading of Duchenne's work, whilst novelty, cheapness, and simplicity at once made it popular: it was more readily kept in order; there were fewer elements, fewer connections; it was seen, heard, and felt; doctor and patient knew, by sparks and buzzing, by nerve-shocks and muscle-jerkings, when the apparatus was at work, whilst the cumbersome and expensive galvanic current, especially if properly used, gave no appreciable effect; the patient was not satisfied; a slight burning, perhaps, but no shocks; nothing so startling or effective, as it would seem; and the doctor, before the days of the galvanometer, often in doubt whether his battery "was working" or not.

Faradism was the one form of electricity used in medicine; the scientific researches of du Bois-Reymond and Pflüger, in 1850, upon the electrical phenomena in living animal-tissue, were the first evidences of recurring interest in galvanism. In their studies of the effect of the anodal and cathodal opening and closing currents upon nerve and muscle, which proved of such diagnostic import, the induced current played but a secondary part; and when, in 1855, Robert Remak, of Berlin, disclosed the merits of the constant current, which he looked upon as the only practically-useful form of electricity, galvanism assumed a supremacy which it has ever since retained,—in the main, I believe, because it appeared of greater import and excited a more general interest as being the form of electricity which first served industrial purposes.

Amid the triumph of galvanism the excellent work of Tripier, who, in 1860, presented to the French Academy a sledge instrument constructed by Gaiffe, with a series of coils, both primary and secondary, of varying length and thickness of wire, made no impression whatsoever, receiving but passing notice even in his own home. His name to-day is almost unknown, though the results of his labors are now appearing; he demonstrated the varying therapeutic effects of currents from differently-constructed secondary coils, and devised the first instruments for bipolar faradization of uterus, vagina, and bladder, which have recently been

elaborated and have guided Apostoli to his valuable methods of bipolar faradization.

The enthusiastic teachings of Remak excited renewed interest in electricity; "as with each important discovery men's minds turned anew to this strange agent extravagant hopes were again aroused, only again to be followed by failures;" so that, when the recoil came, and a calm survey of results actually accomplished followed the first enthusiastic laudations, the current almost fell into disrepute, as practically useless and but the agent of quackery. During my student days, in the very home of Remak, I was taught that it was without effect for therapeutic purposes, though of diagnostic value in some obscure nervous diseases. Yet from time to time a fresh impetus was given by some new theory, experiment, or discovery, and popular favor was ever readily extended to this mystic and wonderful agent from which so much was expected.

During all these therapeutic fluctuations scientific investigation continued, and wonderful progress was made in the practical application of electricity; medical thought and experiment naturally turned in the same direction, and profited by the results evolved.

A more thorough knowledge of the properties of electricity, the introduction of the polar method,—above all, of measurement and dosage, as first applied by Apostoli in 1884,—made the constant current more tractable and serviceable, and again a great wave of electro-therapeutics swept over the profession, all to the credit of galvanism, crowding out faradic electricity more and more. The persistent efforts of Rockwell have given general faradization a place, as the American method, in therapeutics; Apostoli has perfected and practically applied the methods of bipolar faradization, first indicated by Tripier; whilst my own efforts toward increasing range and efficiency of the current, by variation and increase of interruption and by gradation of coils, however successful, have altered the general situation but little as yet.

Valuable additions have been made to our knowledge of faradic electricity in recent years by scientific investigators, prominent among whom are de Watteville, with his investigations on electrical tension, in 1877; Gaertner, who studied the electrical resistance of the human body, in 1887; and Kraïewitsch, who taught the application of Ohm's law to induction currents, in 1889; Stauffer, on the quantity of induced currents, in 1890; then Weil, on fine- and heavy- wire spools, in 1891; and, lastly, d'Arsonval, the brilliant Frenchman, who has probably done more than any investigator now living to further our knowledge of the physiological effects of the faradic current.

A bar to the progress of faradism is the impossibility of satisfactory therapeutic measurement; although the physical quantity of induced currents can be determined with precision, the measurements so far achieved are no gauge of physiological effect, and even the fundamental laws of electricity fail in certain phases of this current. It can be meas-

ured in micro-coulombs and volts, and milliampères can be determined; yet this in no way indicates physiological efficiency, as character and frequency of interruption and resistance and character of coil may alter these without varying the physical qualities indicated by the measuring instrument. The quantity of electricity remains the same, however much the curve—which is indicative of physiological effect—may vary. Nevertheless, some attempts have been made at direct measurement: a faradimeter was recently promised by an able and enthusiastic American author, whose efforts have so far, it would seem, not been successful. The only instrument which has appeared is the faradimeter of Edelmann, which indicates, by a scale on the slide, the strength of the current from that one coil in volts on short circuit, and for a motive power of 300 milliampères; yet it is no more indicative of physiological effect than a scale marked at pleasure in inches or centimetres. It is a beginning, though incomplete and, I must even add, misleading as a physiological or therapeutic measure.

It may be interesting to sketch, in a few words, the development and present status of the apparatus which furnishes the induction current for medical purposes, and I am sorry to say that it well demonstrates that no progress has been made for decades since the completion of the galvano-faradic instrument, when it displaced the earliest forms of the magneto-induction apparatus.

Any instrument of the present day, of whatever make, on either side of the Atlantic, is perfect in one way; "it works well," is well made, extremely satisfactory for the price, and can be had in suitable shape for any purpose the practitioner may desire, as pocket, box, or stationary battery. But whilst all instruments now made function well and "buzz" smoothly, the great majority furnish but *one form of current*, thus greatly impairing their utility, and to this fact mainly is due the secondary position occupied by the faradic current, as well as its limited therapeutic use. The average instrument of the day is not equal to that of Duchenne, with its efficient primary, or coarse-coil, current, and is inferior to the one constructed by Tripier, in 1860, with its series of coils and variability of interruption. Some few makers, appreciative of the wants of the profession, are now furnishing superior instruments, which admit of the application of the widely-different forms of the faradic current, so essential to its efficient therapeutic application; greater range is being given to the coil and to the rate of interruption; in fact, greatly improved instruments have quite recently appeared.

Present Status of Faradic Electricity.

The preponderance given to galvanism by the labors of Remak still prevails, and has of late been strengthened by the striking effects of electrolysis, by the perfection of the polar method, and the possibility of measurement and dosage; the efforts of individual workers in the

field of faradic electricity availing but little to improve its status. Galvanism is in fashion, and fashion is a power in medicine. The faradic box is stowed away, its use is to a great extent confined to those who still deem one form of electricity as good as another, or choose their instrument for its cheapness,—a curious state of affairs in this progressive age, due to lack of interest on the part of manufacturer and electrician, scientist and practitioner, to the inferior character of the average instrument, and to ignorance of the physical and physiological properties of the induced current, which is a *terra incognita* to the majority of those who use electricity in medicine, and even but little explored by the more advanced; yet light is dawning, more perfect instruments are being furnished, and scientific investigation is perfecting our limited knowledge of this neglected form of electricity.

A brief review of assertions made in even the most recent text-books and publications by prominent writers will at once reveal the vagueness and uncertainty of present knowledge in this sphere, and may serve to explain the distrust and disregard of the practitioner for this form of electricity :—

In the International Electrical Congress, held in Frankfurt in 1891, one of the questions under consideration was "whether therapeutic results *can* be achieved by the current which can *not* be achieved by *suggestion*," and much stress was laid on suggestion as a main factor in electrical treatment, prominent in the effects claimed for static electricity, though less so in faradic and galvanic applications. Another speaker expressed the opinion that, in the use of the faradic current, the irritating action (reizende Wirkung) alone is directly or indirectly serviceable in treatment; the sedative, nerve-quieting, effect he did not mention. The Edelmann faradimeter, which is not by any means, as was intended, a therapeutic meter or measure of faradic electricity, he recommended for the laboratory or for the specialist, though too complicated and expensive for the practitioner, and, in citing the instruments necessary for therapeutic purposes, "der kleine Spanner," one of the small-sized faradic boxes, without variation of coils or interruptions, is recommended as answering all demands; and for purposes of measure, dosage, and comparison the number of interruptions and size of electrode are named; yet no means of determining or of varying the number of interruptions is given, and the main features, character, and position of coils and resistance of body are ignored.

The Edelmann faradimeter, here quietly accepted as a measure of faradism, is another evidence of the darkness still enshrouding this current; it has been accepted because it emanates from one of the most competent and scientific of electricians, with the assistance of a prominent electro-therapeutist, and is presented by them to the profession as the first instrument for the measurement of the induction current, which is to remove that stumbling-block to the progress of faradism,—the absence of measure. And what does this instrument accomplish? It records the voltage of the current in short circuit, *i.e*, as measured directly, unimpaired by any obstacle, without body resistance, and is hence merely a deceptive snare for physiological or therapeutic purposes, as the tissues permeated, or character and extent of resistance, which is here ignored, vary the current value in the most surprising manner; for instance, the heavy coil, when in perfect juxtaposition, gives a current of 240 volts by the Edelmann faradimeter, and yet this has but an imperceptible physiological effect when applied through a high body resistance; whilst the fine coil, which, in the same position, indicates only 180 volts, has a powerful effect, and, on the contrary, when applied through a low resistance, as in visceral or bipolar faradization, the intensity and efficiency of the 240-volt current far exceeds that of the 130 volts.

The strength of the current would be far better approximated by indicating the nature

of the coil and the resistance offered than by the volt scale of this faradimeter; yet it is a beginning, and a move in the right direction, not to be confounded with the faradimeter pictured in an American work, to which I should not again refer were it not to exemplify how lightly this subject of faradic electricity has been treated. The following statements are calmly made of an instrument which does not, and did not then, exist: "With this at our command we can observe and record qualities, tension, and volume of the faradic current used upon a patient in terms of the same standard, the volt, and the ampère." As the instrument has not materialized it is needless to call attention to the fact that the *coulomb*, and not the volt and the ampère, is the electrical unit by which we must measure faradic electricity; and that, as I have already stated, even this is no index of its physiological effect.

Most authors have nothing whatever to say of the tension or quality of the interrupted current, and I refer to works which have appeared in the last few years; but one text-book, on "Electricity in the Diseases of Women," does touch upon the subject, stating that "the volt-force of the faradic current *probably* varies from several hundred to several thousand volts," whilst, as a matter of fact, it rarely attains the intensity of several hundred: the volt-force of a shorter coil varies from 10 to 300 volts, with an inducing current of 300 milliampères and 2½ volts; and that of a fine coil from 5 to 180 volts, as Edelmann states.[1]

Hardly more definite are the teachings in our medical works upon other features of faradism. Thus, the subject of current-break, the essential, the very life of this form of electricity, receives but little, if any, attention. One author passes it over with the injunction "to avoid an instrument which makes a harsh noise," and another limits his demands upon the interrupter to "a clear note" as important in gynæcological practice. The variation in the physiological effect of the current by change of interruption, and the complete control exercised over it by a properly-adapted trembler, which I claim to be a prominent feature, has never been alluded to.

When variation of interruption is spoken of, it is within limits which afford no positive alteration of physiological effect, and a definite assertion is never made, the number of interruptions necessary to obtain a certain effect is never given, and no instrument exists in which a *definite number* of interruptions as *needed* for a *definite purpose* can be obtained at will. Rapid and slow interruption is occasionally spoken of, but the reader is left to infer the meaning of these words; but one author, the most scientific, tells the practitioner how to determine the number of oscillations of the trembler by comparison of its sound or note with that of a tuning-fork of known vibration. Yet this knowledge, acquired with such difficulties, is of little value, as it will be almost impossible to again obtain this same number of interruptions, and practically it is of no importance, as the range of possible variation is insufficient for the obtaining of practical results thereby. A single instrument exists, now in the College of Physicians, in Philadelphia, devised and described by Onimus and Le Gros, in which the rapidity of interruption, within moderate limits, can be defined, but it has never been particularly utilized. I will add that, since writing this, attention has been directed to this point, and efforts in this direction have been made by some of the leading workers.

More detrimental to the therapeutic progress of faradism has been the persistent ignoring of the variable physiological effects produced by currents from coils of varying resistance and electro-motive force or different length and thickness of wire: one author, regardless of what was already taught by Duchenne half a century ago, tells us that "all usable strength and qualities of a faradic current are obtainable from a single secondary coil," and even speaks of the "coarse-wire nonsense"

[1] I note these measurements as recorded by Edelmann, and yet I have my doubts as to their accuracy; my own measurements are not as yet completed, and I prefer to give no imperfect data, but will only say this much, that I find higher ampèrage from the heavy coil, and, as far as I can now say, lower voltage; hence I wish it distinctly understood that I am here quoting from Edelmann, and giving the voltage as impressed on his faradimeter.

as something to be eradicated because it is absurd and confusing to the practitioner. I have myself been thoroughly scored for venturing to insist upon the variability of therapeutic effect produced by coils varying in their relations of resistance to electro-motive force, or coils of fine and heavy wire, and, in short, in a comparison of recent medical literature, we are confronted by vague and contradictory statements, mainly theoretical, without a sound physical, physiological, or therapeutic foundation. Thus, quality and therapeutic effect are estimated by the *feel* of a current to the hand or arm of the investigator. It is upon such grounds (Steavenson and Lewis Jones, "Medical Electricity," London, 1892) that the identity of currents from coarse and fine coils is asserted; and upon similar experiments is founded the statements of Edelmann, that static, faradic, and galvanic currents, with like interruption and like force, are identical, which would be true, provided that change of potential, volt, and ampère force were similar,—an impossibility from the very nature of these currents; but, because a single impulse from an approximatively similar faradic and galvanic current cannot be distinguished by the healthy tissues of a blindfolded observer, we cannot assert identity of quality and therapeutic effects. Let such reasoning cease. *Feel* is no indication of quality or effect; the *feel* of the mustard plaster and the same-sized plate electrode with a proper galvanic current is not to be distinguished, nor is that of the slowly-heating cautery point and the galvanic needle, the heated metal and the galvanic plate electrode. And yet, is the character of the agent and the effect produced one and the same?

Even the electrician or the physicist adds to the existing confusion when he seeks to arrange electro-physiological and electro-therapeutic facts in harmony with the elementary laws of electro-physics, unconscious of the fact that the human body does not react like a bar of iron or a coil of wire; that measurement in electrical units is not a measure of physiological effect; that a current of high tension and great quantity may have a minimal physiological effect, whilst a current of low tension and small quantity may act with the greatest intensity; and that even Ohm's law ceases to hold good upon the human body when currents are interrupted with sufficient rapidity.

We can hardly wonder at this unfavorable condition of affairs when every idea of quality and quantity is wanting; when even the effect of the current is doubted or but vaguely acknowledged; when its effect is judged by the *feel* it gives to the hands of the investigator (Steavenson, Edelmann, and others); when it is questioned whether the effect of the current is not mainly suggestive or psychogenic (Electrical Congress, Frankfurt, 1891); when an irritating effect alone is ascribed to faradic electricity (*idem*), or its effect is strictly limited to "conditions which exhibit nerve- or muscle- weakness" (Massey),—in itself by no means a narrow or unimportant field; when the average small faradic box is

advocated as answering all purposes (Frankfurt Congress); and when the choice of a faradic apparatus is deemed of little consequence, and the details, such as character of secondary coil, "can safely be left to the judgment of the manufacturer," and "the clear note of the spring interrupter" is cited as *the one* mechanical detail which requires looking into.

A solution of these complicated questions, and an understanding of the intricate phases of faradic electricity, can be obtained only by scientific research, by physical, physiological, and therapeutic experimentation; indeed, the progressive work of individual investigation is now beginning to lift the veil, yet obstacles of various kinds bar the way to the development of faradic electricity as a satisfactory therapeutic agent: we are under the sway of galvanism, and the recently-introduced alternating current, like all novelties, is detracting from the longer-known forms of electricity; so that we can but trust to the energetic work of those interested in faradic electricity, and to the perception of the profession, that they overcome these influences and accord the proper place to the interrupted current.

It is not a question of the respective merits of these various forms of electricity, as each has its own especial sphere; and that of faradism, though it can never supplant galvanism, is far broader and more important than the profession now take it to be, and that of the alternating current must yet be determined.

II. INDUCED CURRENTS.

Every *change*, be it of *force* or *position*, in a magnetic or galvanic field, gives rise to a current of electricity in a conducting circuit near to, but not in contact with, such field. Currents so produced are called induced currents; they are, as ordinarily developed (unless the change in the inducing force is of infinite rapidity), subject, like other currents, to the law of Ohm, and are gauged by one or the other of the standard units of electrical measure.

Induction currents are of short duration, persisting only during the persistence of the change in the magnetic or galvanic field, the change in the inductor or inducer: and, as their existence is dependent upon a change of force or position, and their intensity co-ordinate with the rapidity or intensity of this change, the potential never for an instant retains its primitive value; it is constantly changing, and never attains a permanency.

A. Kinds of Induced Currents.

In accordance with the kind of force and change in the inducing field we distinguish between magneto-induction currents and galvano- or volta- induction currents.

I. MAGNETO-INDUCTION CURRENTS.

The magneto-induction current is developed by a *change of position* between inducer and induced, between a magnet and a closed circuit, the latter being the secondary coil to the ends of which the rheophores are attached. This is accomplished by rapidly approaching and again removing the induction coil from the magnet, or, as it was more commonly done, by a rapid revolution of the magnet, thus approaching and removing it from the coil, each motion generating a current, but in opposite direction to the other. The strength of this current increases with the strength of the magnet, the rapidity of movement, the number of windings in the secondary coil, and the approximation of the coil to the magnet. This was the principle upon which the earlier rotary, or magneto-electric, instruments were constructed; but as this current is no longer used in medical practice, and, moreover, presents the same general features as the galvano-induction current, we will not elaborate it.

II. THE GALVANO-INDUCTION CURRENT.

The galvano-induction current is developed within a neighboring secondary circuit by a variation in the flow of force in the galvanic field: *one* current is generated by the *increase*, and *another*, in opposite direction, by the *decrease*, in the flow of force. This current increases in strength with the strength of the generating galvanic current in the primary circuit, with the number of windings or lines of force in the secondary circuit, and with the approximation of these circuits,—of the inducing force to the induction coil,—but also with the brusqueness of the change in the flow of force.[1]

The theorist knows, and the practitioner to his regret may have discovered, how greatly variation influences even the direct galvanic current. Whilst a continuous current of 200 milliampères may be applied without pain in gynæcological treatment, when *slowly* increased to that intensity, *rapid* increase is very painful, and *sudden* making or breaking would be almost unbearable. The indirect or induced current, however, owes its very existence to variation of force, and is greatly intensified by the brusqueness of that variation, which reaches its climax in the sudden making and breaking of the current.

As the physiological effect of the current induced in the secondary circuit is proportionate to the rapidity of the variation, or the intensity of the change, in the flow of galvanic force in the primary or inducing circuit, we obtain the most effective induction current by the most rapid and extreme change of force in the inductor; that is, by the sudden change from 0 to the full current-force, and again by the fall from its highest efficiency to 0,—that is, by the instantaneous making and breaking of the current. Gentle variations of the galvanic flow in the inductor

[1] This is true as regards the physiological properties of the current, and to a certain extent as regards its physical properties, although these are not co-ordinate.

do not produce induction currents which affect muscle or nerve, but it is the *brusque*, *sudden* change which does achieve the physiological effect.

III. WHY THE GALVANO-INDUCTION CURRENT IS PREFERABLE.

The effect of the induction current being due to variability of status, the highest efficiency can never be achieved by magneto-electric currents, produced by a change of the relative position of magnet and coil, which can only be progressive, approximative, but never instantaneous; hence, for practical purposes, the galvano-induction current is used, but its efficiency is increased by the plus of a magneto-induction current produced not by actual approach and removal of a magnet, but by the more effective sudden magnetizing and demagnetizing of a soft-iron core, within the coil of the primary circuit, by the making and breaking of the inducing current: thus, two currents are induced in the neighboring circuit or secondary coil. It is known that if an inducing circuit is traversed by *one* current and *another* is induced *at the same time*, its effect is increased thereby if this current is of equal polarity or in the same direction, and diminished if in contrary direction: thus, the magneto-induction serves to strengthen the volta-induction current. The current developed by the making of the galvanic flow—the make or closing current—is contemporary and equipolar with that produced by the approach or make of the magnet,—the current of magnetization,—as the break or opening current is identical with that of demagnetization; hence, the resulting induction is as the united product of the two forces.

B. Medical Currents.

I. FUNDAMENTAL LAWS.

For a more thorough understanding of the current as applied in medicine we must recall the fundamental principles of faradic electricity. The establishment, variation, or cessation of a current produces polarizing effects in a neighboring circuit, as proven by the passing current if this circuit is a parallel wire, or by the magnetizing effect if it is a bar of iron, at right angles; and *vice versâ*, variation, relative or absolute, of a magnet causes currents in neighboring circuits, whose direction, intensity, and duration are *in direct relation* to the direction, intensity, and duration of the *change* in the magnetic inducing phenomena.

A current which is established or approximated causes a current in opposite direction in the neighboring circuit: a current which ceases, is removed, or passes away causes in the neighboring circuit a current or a polarity of the same sense or direction as the one in the inductor. These *induction* phenomena all depend upon a *variability* in the inductor, either of condition or position; they cease as soon as permanency is established, in either form of change. *Direct* induction currents are those produced by the negative variations, cessation, opening, or re-

moval, and are in the same sense or direction as the current or polarity of the inductor. *Inverse* currents are those developed by a positive variation, by establishment, increase, or approach, and are in opposite direction to the inductor.

Self-Induction.—Any variation in the flow of force in a circuit develops a current within its own conductor, and this product of self-induction, the extra-current, is in contrary direction to the producing current, and weakens it. The extra-current of make or close is inverse to the current proper of the circuit, or indirect; that of opening or break is in the same direction as the inducing current, or direct.

Direction.—If an observer be swimming in the magnetic field in the direction of the lines of force, which enter at his feet, the current produced by a variation passes from his right to his left. The direction of a current induced in a circuit by any variation in the flow of force is such that it, at every moment, opposes the movement which produces it: if the flow increase,—approach of the magnet or making of the current,—the induced current opposes its increase and existence; that is, it is in the opposite direction to the current which produces it: if the flow decrease,—removal of magnet or breaking of current,—the induced current opposes the diminution, *i.e.*, it is in the same direction as the inducing current.

The *duration* of the induced current is equal to the duration of the variation in the flow of force which produces it.

The *quantity* of electricity is equal to the variation in the flow of force (independent of its duration) divided by the resistance of the circuit.

II. DESCRIPTION.

We can, then, picture the medical current as follows: a galvanic field, consisting of a loop of wire as primary circuit, through which a current is passing from a battery, B, and surrounding this, but not in contact with it, a turn of wire, C″, as secondary circuit. A steady current now flows through C′ from P to N, which is without effect on C″; let the wire be broken at I, and no current can pass; but if the contact is suddenly made, the circuit, C′, completed by uniting the wires at I, an induction current is produced in C″, at the making of the current in C′, in contrary direction to the primary flow of this force, and this again induces an extra-current co-ordinate with itself in C′; so that we now have in C′ the battery current, weakened by the opposing extra-current; but let the flow of force through C′ continue steadily without change of potential, all induction effects will cease as completely as if no current permeated the inducing circuit. If, now, the current in the primary circuit is broken by disconnecting the wire at I, the potential is reduced and another current is established in C″; this is in the same direction as the inducing current, and, reacting upon C′, establishes an extra-current

in the primary circuit, which is in the same direction as the original battery current. The current in C′, both at making and breaking, is in one and the same direction,—the primary is always a direct current in the same direction, of the same polarity with the inducer,—while that in C″

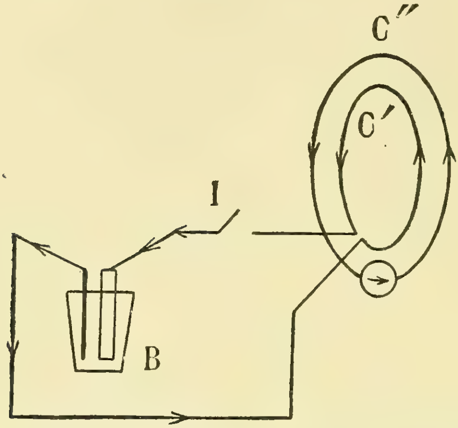


Fig. 1.—Simple Primary (C′) and Secondary (C″) Circuit at Break or Opening of Current.

alternates: at making of the current it is in an opposite direction to the inducing current and the current in C′, an inverse current, and at breaking in the same direction with it, or direct. The flow of galvanic force is feeble, and the magnetic force produced by a single circular turn or wind of wire is small; hence, to increase this force, a number of turns

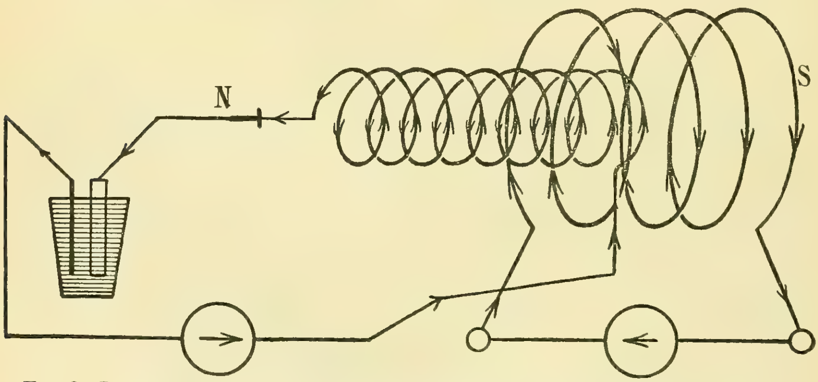


Fig. 2.—Lines of Force Increased by Turns of Wire, Forming a Solenoid Current as Found on Closing or Making of Circuit.

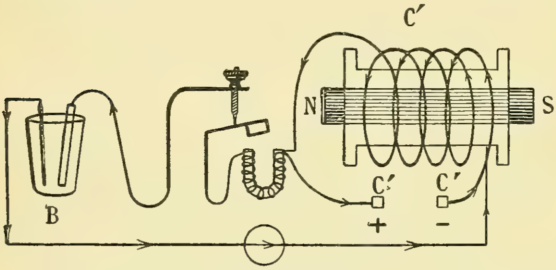
are employed for the primary circuit, C′ (Fig. 2); these are made by the winding of copper wire over a cylinder, and a solenoid is thus formed. The induction force of the secondary circuit is likewise augmented by an increase of the number of lines of force in the concentric superimposed secondary coil.

If we regard the solenoid of the primary circuit as a magnet, as it actually is upon closing of the current at I, its polarity will be such, N—S, that the current induced in C″ opposes its increase and existence by its contrary direction, whilst with the breaking of the current this magnetic polarity momentarily disappears, to be at once re-established in the same direction by influence of the current established in C″ by the break in the primary flow; the break current as opposing the movement of diminution or demagnetization must be one of make or magnetization; hence in the same direction as the original galvanic flow. It appears from this that the currents induced in two conaxial solenoids at making of the current, and making or approach of the magnet, are such that the current in the secondary coil is in contrary direction to the one in the primary, while the secondary current of break and demagnetization is equipolar with it (in the same direction as the primary). Other conditions unchanged, the induction effect is increased by an increase in the change of potential in the inducing circuit,—*i.e.*, in rise and fall of the magnetic force in the primary coil, which can be attained, without increase in battery force, by placing a bar of soft iron within this coil. The lines of force in this solenoid may be likened to those of a long, thin magnet; and if an iron rod is placed within its axis, the lines of force will pass through this rod and magnetize it, and, on account of the greater conductibility of soft iron for lines of magnetic force, they will be concentrated therein, and more lines will then pass through the solenoid than if the iron were not there; practically we utilize a bar of soft iron within the primary circuit, and thus develop more lines of force in the space around the solenoid; we create a more intense magnetic field, and heighten its efficiency. This core, by its successive magnetization and demagnetization, on make and break of current, acts as an inductor upon the two surrounding conaxial circuits, and acts in the same sense as the primary galvanic current. Moreover, it serves, in the simpler forms of apparatus, alternately as magnet and neutral body to an iron spring-head, which causes the opening and closing of the battery circuit, thus acting as an automatic interrupter, by means of which the most effective and physiologically active induction currents are obtained from the primary galvanic flow: the variability in the flow of force, which produces the induced current, thus attaining its limit, as the most abrupt increase and decrease of current and approach and removal of magnet is obtained by the sudden making and breaking of current and magnetizing and demagnetizing of core and solenoid.

The fluctuation of force in the *primary* circuit acts not only upon the neighboring secondary coil, but reacts upon itself (self-inducing),—a reaction which is greatly augmented by the increase in the magnetic powers of the circuit by the core of soft iron. These currents, resulting from self-induction, are called extra-currents, and, from the laws enounced,

it is evident that the extra-current of make, or magnetization, is opposed to the primary current of make, and weakens it so much that it may be disregarded, whilst that of break, or demagnetization, is co-ordinate with the battery current, and is as a plus to the flow of force in the primary coil at break; hence, although make and break currents in the primary coil are both direct, in the same direction as the battery current, the latter preponderate to such an extent that we take account only of the current of break and demagnetization.

The *induction* currents proper, in the *secondary* coil, are quite different in character; the inverse current, induced by closing of circuit and make of the magnet, takes effect as well as the direct current of opening and demagnetization. Although these currents are alternating, in opposite direction, it is customary to attribute one direction, or polarity, to them, which is always that of the current of break, or demagnetization, as its intensity and physiological effect is far greater than



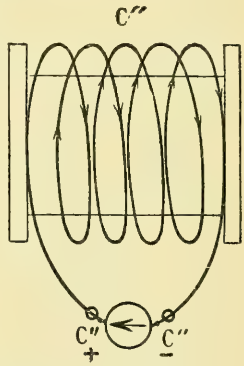


FIG. 3.—FARADIC APPARATUS, SHOWING CURRENT OF MAKE AND MAGNETIZATION.

that of the make current, though equal as to quantity. The curve of the direct or opening current is more brusque, the variable stage to which it owes existence being more brief than that producing the make current; hence its greater physiological efficiency. We now have this condition of affairs (Fig. 3): 1. A galvanic current sweeps around the primary coil, C′, which (*a*) converts the core into a magnet, N–S, and (*b*) induces a momentary reverse current in the secondary coil, C″. 2. The sudden magnetizing of the core itself induces a reverse current in the secondary coil, which strengthens the galvanic induced current within this circuit. 3. The magnetized core attracts the soft-iron head of the spring to itself, and so breaks the current-flow. 4. This stopping of the current-flow stops the magnetizing influence upon the core, and a direct current is induced in the secondary coil by the breaking of the primary current, strengthened by that induced by the demagnetization of the core. 5. The magnetic force holding the hammer being removed, it returns, by the tension of the spring, from the core to the battery-wire, whereupon another current passes, and by these vibrations the process is repeated in such rapidity as the strength of spring and magnet admits.

III. CHARACTERISTICS.

The faradic current, although the product of induction, is an electric flow with all the properties of the electric fluid, which vary in degree only in three forms in which it is employed in medicine, as galvanic, static, and faradic electricity, and we may now add, as a fourth, the alternating current. The faradic, which resembles the lately-introduced alternating current, being, as it were, an intermediate between galvanic and static, is characterized by the brusqueness of its curve, and by its variability, interruption, and alternation, as compared to the constant and continuous galvanic, with less quantity or ampère force than this, and higher ampèrage, though less voltage, than the static. The galvanic current, as used in medicine, has great quantity with low voltage,—from 1 to 300 milliampères, with from 2 to 40 volts; the faradic has less ampèrage and higher voltage,—$\frac{1}{100}$ to $\frac{1}{10}$ milliampère, with from 10 to 250 volts. The static has a minimal quantity, not over $\frac{1}{1000000}$ ampère, or $\frac{1}{1000}$ milliampère, and the highest voltage, from the hundreds upward. The alternating current is used by Apostoli with from 32 to 64 volts. These conditions may be graphically demonstrated by the flat, voluminous curve of the galvanic current, the abrupt, brusque curve of the faradic, and the still more abrupt ascent of the static. Yet the properties of the fluid in these various forms of its application remain unchanged as those of water, whether flowing in the broad channel of a stream, hurled in jets from the nozzle of a hose, or escaping as steam from the valves of a boiler.

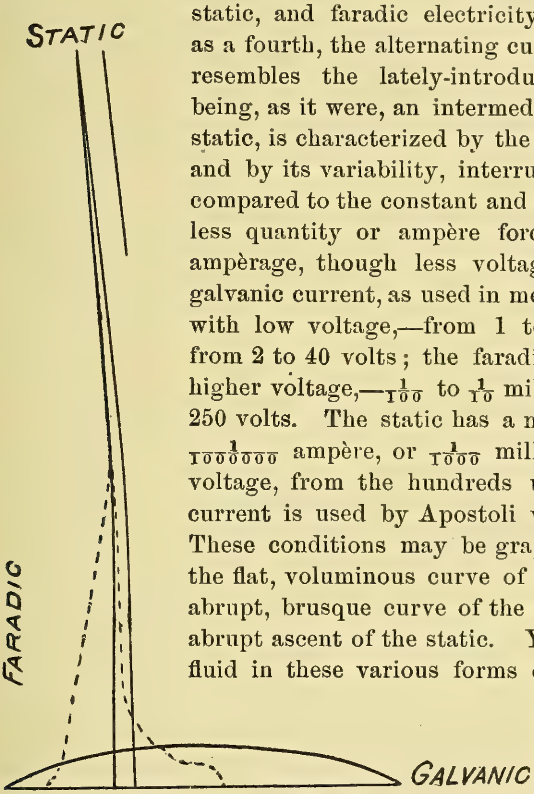


FIG. 4.—CURRENT CURVES.

The curve of the primary current differs greatly from that of the secondary, as it differs in measure, sensation, and physiological effect; sense or direction, duration and intensity of both currents is well represented by Fig. 5 (Edelmann), which shows us the primary flow, *M N*, alternately made and broken every second; *a b*, *b c*, *c d* indicate the duration each one second, whilst *a f*, *b g*, *c h* represent the intensities of primary (battery) flow.

On make or closing of the current, at the beginning of the second *a b* the primary flow is inauguarated, attains the intensity *a f*, at which it continues until the opening or break at the close of the second *b*, when it suddenly sinks to 0. To this current are added the extra-currents of the primary circuit, on make, at *a*, an extra-current in a contrary sense, reducing

the force of the original flow at f, and at b, break, in the same sense thus strengthening the flow at g. This make and break of the primary flow induces the contemporary current impulses A, B, C, D, in the secondary circuit; the less-powerful impulse, or current of make, A, C, being in a contrary sense to the primary flow, whilst the break current, B, D, which practically is alone to be considered, is in the same direction.

The primary flow continues whilst contact persists, but the secondary lasts only as long as the change of force in the primary flow on make and break, and its intensity is proportionate to the intensity of the primary as influenced by its extra-currents at the moment of make and break.

In speaking of the faradic current it is virtually the opening current, the current of break and demagnetization, which alone is considered, as it is the preponderating element in both primary and secondary coil, and determines polarity or direction, as well as intensity, of the

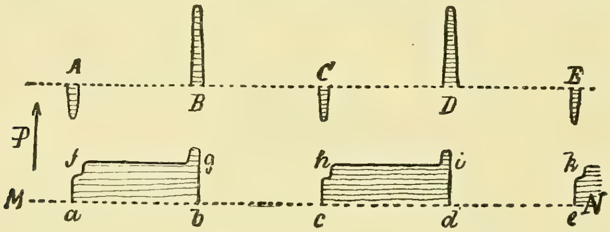


FIG. 5.—SECONDARY AND PRIMARY CURRENTS. (EDELMANN.)

currents. In the primary circuit the closing current is reduced by the induced extra-current, which is in the same direction as the opening current, and aids it so that the opening current is the sum of the induced electro-motor force, and that of the inducing circuit itself, with a greater quantity of electricity, as indicated by the galvanometer, and with greater physiological effect. For the secondary coil the galvanometric quantity of electricity, as measured on short circuit, is the same for both opening and closing current; but as the physiological effect of the former is greater, it is the opening current alone which is considered; this is of shorter duration, and, the same energy being expended in a shorter time, is of higher tension, and its effect on muscle and nerve is greater; it is the controlling factor, as far as physiological and therapeutic purposes are concerned, and is alone considered, to the exclusion of the make or closing current.

The opening current is formed and completed in about 0.000275 second, and the closing current in 0.000485 second, the ratio of potential being as 6 to 13 for a current of this character. The duration of the current of opening is shorter, its curve more brusque; its tension and power to overcome the body resistance encountered in all therapeutic applications is greater, and this preponderance over the closing current

increases with the increase of resistance. With large moist electrodes, or in the electric bath, the physiological effect of opening and closing current is the same: this is with lowest resistance, as we see also the identity of physical effect in the sway of the galvanometer needle when resistance is 0. As resistance increases, the preponderance of the opening current steadily increases, until with the highest possible resistance, as in the high-tension, single-wire current, we cease to see any effect from the closing current, whilst that of the opening current is marked. So in physiological effect, and the same is true of the high-tension current in physical effects, a flash lights up the electric lamp on opening, whilst no result is visible on closing. With more moderate resistance the deflection of the galvanometer needle proves to the eye this preponderance which the sense of feel readily discovers. The resistance of the body varies with the tension of the current, being less as the tension increases, less for the faradic current than for the galvanic, and varying likewise for the faradic itself; less for the fine coil than for the coarse coil, and less for the current of opening than for that of closing; only when the body resistance is reduced to a minimum do we find an equality of physiological effect in the currents, but this is a condition rarely attained in medical usage, with the exception of the faradic bath. The more brusque curve of the opening current is well demonstrated by the spark, which is larger on opening than it is on closing of the circuit, although produced by the same amount of electricity; the same energy is expended in a shorter time, and produces a greater effect. This spark, which serves no purpose but to convey the extra-current of opening to the primary coil, consumes a large percentage of the current-energy, of which some 25 per cent. is lost, much of this being converted into heat in the spark.

The actual current-energy is indicated by $I \times E$, or the current-intensity multiplied by the electro-motor force,—the number of windings in the coil (always remembering that E is actually $E - E'$, as we shall see later); in the secondary current it is only three-fourths of that in the primary. Like opening and closing current, so anode and cathode vary in physiological effect: the *cathode*, or negative pole of the faradic current, has a greater effect on motor and sensory nerves, and can always be recognized thereby. The closing contraction will be first observed at the cathode, the opening contraction at the anode. Weak currents contract only at closing in both directions of the current; moderate currents show a stronger closing than opening contraction, and very strong currents contract only at opening with ascending currents, and at closing with descending currents. The effect of the poles on sensory nerves is similar: whilst the closing contraction may be said to be cathodic and the opening contraction anodic, both poles have a certain sensory influence, but the closure (cathodic) excitation is greater than the opening (anodic) excitation.

The difference in the effect of the poles, like that of opening and closing current, increases with the resistance, and here also we see the most striking difference in the high-tension single-wire current, a bright glow being obtained from the negative pole, with the positive grounded; but if the 118-volt lamp is connected with the positive pole, and the negative is grounded, the light is more dim and intermittent or flashy. Coils of high electro-motor force are necessary for these experiments.

IV. VARIATIONS.

The faradic current is a most pliable and variable form of electricity, subject to changes (*a*) in *intensity* and *quantity* and (*b*) in *quality*, by alteration in the current-giving apparatus and in the method of application, thus making it possible to obtain a variability of physical and physiological effects and giving it great therapeutic possibilities.

(*a*) *Variations in the strength of the current* are of two kinds, either in physiological effect not measurable, or in quantity, as indicated alike by measure and effect. The first, obtained by insertion or withdrawal of the tube of Duchenne, by variation in the rapidity of the contact-breaker and by variation of resistance, I will not here discuss, as it is of little importance compared to the last, the now universally-adopted sledge movement of the secondary coil. The tube is used only in small pocket-instruments, and, while varying the shape of the curve, does not alter its size, a diminution of intensity being accompanied by a corresponding increase in the time of the discharge, and *vice versâ;* so that the product, Q, or quantity, which is always equal to $I \times T$, remains unchanged. Change of resistance varies the effect of the current and its quantity in a given manner, being inversely proportionate to I; yet the rheostat would be an unnecessary addition and unsatisfactory for measuring purposes, and the influence of varying body-resistance upon the faradic current is hardly to be considered as a means of varying the current-effect. Surface-resistance, determined by character of electrodes as well, and also the number of interruptions, vary the strength of the current, but they likewise vary its quality, and should rather be considered under that head. As the influence of the interrupter as a controller or influencer of current-strength is an entirely new feature, I will briefly outline this method.

The current-strength, or rather its physiological effect, is gradually though slightly increased by an increase in the rapidity of interruption up to a certain speed of the contact-breaker, and then diminished by increase in the rapidity of interruption. We see this exemplified by Coil III, short, 1458 winds, 79 ohms resistance, as follows: with high resistance, small metal electrodes to upper and lower arm, the first sensation on single impulse is not experienced until 45 of the scale; whilst a slow beat, 150 per minute, is felt at $40\frac{1}{2}$, and the more-rapid interruption, 4000

per minute, is already felt at 34. Muscle-jerk is obtained at 63 on single impulse, at 52 with slow interruption, and at 43½ with rapid. The greater the current-strength, the greater the number of interruptions necessary to reduce the current to 0, or to annul its effect on the sensory nerves; but before this point is reached the muscle ceases to respond, a rapidly-interrupted current, to which the muscle no longer reacts, still influencing the sensory fibre.

A moderate current, such as that from Coil III of the Engelmann battery (W. & B.), at 45 of the scale (or ⅓), is sufficient to produce muscular contractions with 45 to 1000 interruptions per minute. This current grows stronger with an increase in the rapidity of interruption up to 4000 per minute, then soon decreases,—muscular contractions cease; at 6500 sensory nerves almost cease to react,—a current effect is barely perceptible; and before 10,000 is reached it ceases to be felt altogether. If the current is a strong one, as it is from the fine Coil III completely overlapping the primary, with an inducing force of 4 Leclanché cells, and applied through large, moist electrodes, a current too strong for ordinary therapeutic applications, the number of interruptions necessary to reduce its physiological effect to 0 must be greatly increased; but if pushed to 28,000 per minute, even this strong current will not be felt, whilst at 25,000 it is still perceptible. The rapidity of interruption controls the physiological effect of the current as perfectly as the sledge movement of the secondary coil; so that, all other conditions unchanged, it is an index of current-strength, and might be used as such with well-regulated interrupters.

To demonstrate this current gradation by variation in the number of interruptions I will cite a single experiment. Coils I and III of the Engelmann battery are used, with an inducing force of 300 milliampères and 5 volts (on short circuit, about 75 and 60 volts, respectively, by single impulse), applied by moist electrodes, three by four inches, to upper and lower arm, giving a moderate resistance (3000 ohms), which almost determines equality of coils:—

Number of Interruptions per Minute.	Coil I.		Coil III.	
	First Sensation.	First Distinct Muscle-Contraction.	First Sensation.	First Distinct Muscle-Contraction.
	Position of Coil on Sledge Scale, in Millimetres. from Point of First Contact.			
1600	5	15	5	22
3500	10	20	15	25
6500	15	25	25	30
11000	20	30	27	34
13200	27	35	32	35

Whilst not actually applicable for purposes of measurement, this table will serve to show the importance of the contact-breaker and the necessity of noting the number of interruptions if any distinct idea of current-strength is to be obtained, and it is self-evident that, for the regulation of current-intensity, the type of apparatus hitherto in general use must yield to more perfect and accurately-constructed instruments which admit of a regulating and recording of the interruptions.

Variations in the quantity of the induced current, comparable to the galvanometric measure or value, are obtained by the sliding of the secondary coil over the primary. This is the method in general use for the regulation of current-intensity. Its mechanism is simple; the current-strength is readily seen by the position of the coil, and noted by the scale marked on the sledge. The electro-motor force is indicated with approximate precision by the arbitrary divisions of that scale, as it is nearly proportionate to the distance between the centres of the coils. This method of varying the current-strength has been long since adopted, and has served for record by the placing of a scale on the slide; and we can now appreciate its advantages over other methods more fully, since we know that this change of position indicates a change of force which is measurable, and that its galvanometric measure corresponds more nearly with the physiological efficiency of the current than do changes of other kinds.

(*b*) *Variations in Quality.*—Of the greatest importance to the medical man are the variations in quality and physiological effect of the current; so much so that I may say that upon this factor depends the therapeutic value of the induction current. These current-changes, by which the most varied therapeutic results can be obtained, are produced by variation in the secondary coil, in the rapidity of the contact-breaker, and in the extent of surface-resistance. Whilst the current-strength is likewise varied more or less thereby, this is of minor consequence, and, as we have in the sledge a method superior in every way to attain this end, I shall consider only the essential feature, variation of physiological effect or quality. Each element is characterized by an individuality of action, and must be separately described; and yet, in proper combination only is its highest efficiency and the greatest variability of physiological effect obtained. Thus, the short secondary coil of heavy wire is characterized by its effect upon muscle, especially the muscular fibre of internal parts, where the resistance is reduced to a minimum; but this is by no means true under all conditions and for all purposes, and to attain its greatest efficiency in this direction the coil must be combined with low surface-resistance and slow interruption of the primary flow. The long coil of fine wire is characterized by a sedative and anæsthetizing effect, but this is only with diminution of surface-resistance and great rapidity of interruption; with moderate interruption and high surface-resistance its action is quite to the contrary,—revulsive. Whilst great

rapidity of interruption determines a nerve-quieting effect of the current, this is only true of currents from long, fine coils, and applied with low surface-resistance; thus, we must utilize the different means of varying the current-quality to attain the most perfect results, yet each acts independently of the other and in a manner peculiar to itself.

The secondary coil greatly influences the physiological effect of the induction current by variation in length and thickness of the wire used in its construction,—that is, variation of resistance and number of winds,—upon which quantity and electro-motor force, or tension, of the current depend. These are the features which influence its characteristics most decidedly, and not whether it be from primary or secondary coil, as Duchenne supposed, who observed the effect correctly, but was misled in his reasoning. We now know that effects which he obtained from the primary coil, and naturally attributed to it, were due mainly to the character of that circuit, and are very similar to those produced from a secondary coil of similar character, and that the apparently peculiar effects of the secondary coil are due mainly to the fact that this was always constructed of longer and finer wire. The distinction he makes between primary and secondary coils holds good if we consider the primary as a short, heavy, and the secondary as a long, fine coil; hence we have little need of the primary circuit, since we can obtain the same variation of effect more satisfactorily by placing a similar coil in the secondary circuit.

Unquestionably there are some differences of physiological effect between primary and secondary coils, but these are not of sufficient importance for therapeutic purposes as long as we have only the one small primary coil. Until we can obtain a greater range of primary coils, such as I have in connection with a specially-constructed instrument, it is far better that we confine ourselves to the secondary circuits, which admit of comparison and of extensive variation.

The primary circuit, if properly constructed, has a special therapeutic field, from which I have already obtained admirable results; but I am not yet prepared to discuss them, and they are unattainable from ordinary faradic primaries; hence I will not dwell upon these currents. From Duchenne's own statement we see that primary and secondary are practically coarse and fine wire, or low and high, electro-motive-force currents. The five main points of difference between primary (coarse) and secondary (fine) coils made by Duchenne are: 1. The current from the secondary (fine) coil acts more intensely on the retina, if applied with moist electrodes to face or eyeball. 2. The secondary (fine) coil affects the sensibility of the skin more intensely. 3. The primary (coarse) coil affects organs more or less deep under the skin more intensely. 4. The secondary (fine) coil produces more marked reflex contractions. 5. If moist electrodes are used on the skin, the secondary (fine) coil penetrates deeper than the primary (coarse).

I have considered only the striking variations of current as produced by changes in the secondary coil. Upon length and diameter of the wire depends the resistance of the coil and the quantity of the current; the number of windings or turns determine the electro-motor force; hence these details must all be given in defining character and effect of a current, and every coil should be accordingly marked. A short coil of heavy wire is indicative of great quantity or ampèrage, and low tension or electro-motor force; a long coil of fine wire, of small quantity and high tension; each factor has its significance, and it is a mistake to give all importance to the number of turns of wire, or lines of force, as some have done, claiming that a coil of heavy and one of fine wire will have the same effect, provided that the number of windings are the same in each, basing this assertion on the "feel" of the current and the idea of an equality of lines of force, without physical or physiological experiment, and forgetful of the important element of resistance, as varied by thickness of wire. As a matter of fact, the current from two such coils differs in quantity and quality, in galvanometric measure and in physiological effect,—yes, even very much in *feel*. Let us examine two coils :—

Heavy : No. 15 wire = 0.85 ohm resistance, 528 windings.
Fine : No. 40 wire = 180.00 ohms resistance, 528 windings.

The heavy coil preponderates in quantity, or ampèrage; the fine in tension, or voltage. At 100 of the sledge scale, the coils overlapping, the heavy coil gives, on short circuit, a galvanometric force of 25 milliampères, and the fine coil only 0.5 milliampère, or one-fiftieth; with 3000 interruptions per minute (high resistance, 50,000 ohms) and metal electrodes applied to middle of upper and lower arm, the heavy coil causes strong contractions, not at all painful at 100, perfect juxtaposition; whilst the fine coil could not be borne at that point of the scale, and is very painful at 75, yet causing very slight contraction only, the heavy coil producing strong contraction at 50, without any sensation. With moist electrodes two inches square, in the same position, and a resistance of 7000 ohms, the heavy coil causes powerful contractions at 70, with almost no perceptible feel of the current; whilst the fine coil causes strong contractions at 40, yet so painful that they cannot be borne beyond 50. The current from the fine short coil, 528 winds, is an exceedingly sharp one, affecting the sensory nerves, whilst the heavy coil affects these but little, yet acts powerfully on muscle.

Surface-resistance, kind of electrode, and rapidity of interruption greatly vary the current from coils of all kinds, affecting each one differently, so that the effect of a coil cannot be wholely defined without a knowledge of the conditions under which it is used; yet, as a rule, I can say that the short, coarse coil, low resistance, with greatest possible electro-motive force, by prolonged application renders the parts more sensitive; even after a *séance* of ten minutes the current must be reduced to avoid more powerful effects, whilst the current from the long, fine coil,

high resistance, and high electro-motive force, is sedative in its effect, and quickly establishes a certain tolerance; this anæsthetic effect increasing with number of winds, thinness of wire, and rapidity of interruption. In a vagino-abdominal application for reduction of pelvic pain the fine coil was distinctly felt at 35 volts, short circuit, with 3500 interruptions per minute, and after an application of five minutes was moved farther over the primary to 50 volts before it was even felt.

With low resistance, as it is not generally met with in medical use, though decidedly marked in the electric bath and in some bipolar applications, the current from the short, heavy coil is stronger and of greater physiological effect than that from the fine coil; as the resistance increases the fine coil gains ascendency, and with the high resistance usually found it is stronger by far, with greater physiological effect, than the coarse-coil current. Even in the spark we observe the marked difference in effect; the spark from the shorter, heavier coil is shorter, but hotter, from proper instruments giving sufficient heat to melt iron; from the long, fine coil it is longer, but gives less heat.

In a bipolar intra-vaginal treatment with an inducing force of 300 milliampères and $1\frac{3}{8}$ volts, 2500 interruptions, the shorter coil, 2300 winds, No. 28 wire, produced painful sensations at 110 volts, short circuit; whilst the longer coil, 8200 winds, No. 40 wire, was not even felt at 150 volts, *i.e.*, in more perfect apposition with the primary. With 400 milliampères inducing current, a heavy coil of 1100 winds, 3.8 ohms resistance, and fine coil, 11,050 winds, 1030 ohms resistance, high circuit resistance, faradic brush on elbow and hand, the fine coil is intense at 11 centimetres from complete juxtaposition, whilst the heavy coil is not even painful when full in: but if large, moist electrodes are used, the coarse coil at its weakest gives intense and painful contractions, whilst the fine, full in, is painless and the contractions produced are but slight. The less the resistance the less the preponderance of fine coil, until with minimal resistance the coarse coil is strongest.

This weakening of the current is not due to a resistance measurable in ohms, but to a counter-current produced by self-induction; it is a diminution of potential, and not an increase of resistance. The opening current induces a counter-current in its own conductor, and thus prevents the ascending; this counter-current does not change the quantity or the galvanometric effect, and the surface of the curve remains the same at the initial and maximum intensity, but its apex is very much changed. This self-induced counter-current is stronger in the fine coil and stronger with low resistance; hence these peculiar phenomena. The law controlling self-induction currents is this: that they increase in intensity (1) with approach of the circuits, more intense the nearer the circuits, hence greater in their own conductor than in a neighboring circuit; (2) with diminution of diameter of the wire in the coils, hence greater in the fine-wire coil; (3) with strengthening of the current, hence

greater as resistance is less or battery force greater. By self-induction the potential of a fine coil of 1030 ohms resistance through a body-resistance of 3000 ohms is reduced to only 22 per cent. of its original value, whilst that of the heavy coil is diminished much less, remaining at 78 per cent. of its original value.

The electro-motor force cannot be measured simply by the number of winds (Weil), but it is E—E′, E′ being the electro-motor force of the counter-current. According to the nature of the coils their relative strength varies, but for the average extremes of coarse and fine coil equality of current effect at the same point of the sledge is obtained at a body-resistance of from 1000 to 3000 ohms (see experiment, p. 137, showing almost equal effect of coarse and fine coil with variable number of interruptions at 3000 ohms resistance); but with metallic resistance this equality of current, as measured, is obtained at from 200 to 300 ohms (Weil); so that we may see how greatly current effects are varied by changes in any of the determining conditions, and it is evident that the variations of current obtained by differences in the construction of the secondary coil are of the greatest therapeutic importance, and must be recognized by manufacturer and practitioner before efficient instruments and satisfactory results are obtained.

Having found that the highest possible resistance with the lowest possible electro-motor force produces the most painful, irritating currents, and the lowest resistance with the highest electro-motor force the most powerful muscle effect with the least pain, I have improved on the former coarse coil of 0.8 ohm resistance and 528 winds by a coil of fine wire in multiple, giving 6500 winds with 4.1 ohms resistance, and thus obtain the best contractile effects. The most useful coils for general nerve and penetrating effects are with 4000 to 6000 winds, but sedative effects superior to those from such coils I have obtained from coils of 9600 and even 12,900 winds, with resistance up to 2500 ohms. Experiment has shown me the peculiar physiological effects of the differently-constructed coils, and I hope soon to be able to determine precisely and accurately the conditions for various coils, under which they are most efficient for their especial therapeutic purposes.

Rapidity of interruption likewise varies the quality and physiological effect of the current greatly without altering the galvanometric value. The effect of the contact-breaker is such that the strongest currents from the fine coil, in complete juxtaposition, with moist electrodes, can be reduced from a maximum intensity, insupportable to the sensory nerves, to 0, and with such regularity of gradation that *the number of interruptions may serve as measure of current-strength.* Yet I utilize the interrupter merely for the variation of quality or kind of effect; slow interruption, from 5 to 200 or 300 per minute, determining more effective muscular action, whilst the sedative effect upon sensory nerves is more readily secured by rapid interruption,—20,000 to 50,000 per

minute. A current which, with moderate rapidity of interruption, produces powerful muscle-contraction with marked sensation is gradually reduced as rapidity increases, the contractions cease, and it is scarcely felt when the number of interruptions is increased still more; finally it is completely obliterated, yet produces a sedative and even an anæsthetic effect, though no longer recognized by the sensory nerves; this anæsthetic effect persists for a greater or less space of time, according to intensity of current, rapidity of interruption, size of coil, and length of sitting. Coil III, 32 wire, 6000 winds, 650 ohms resistance, at 45 of the scale, with three by four inches moist electrodes and an inducing force of 4 Leclanché cells, produces muscular contraction with 1000 interruptions per minute, and is not felt with 7000, yet produces a sedative anæsthetic effect establishing tolerance; at 100 of the scale, the coil full in, the current is too powerful for motor or sensory nerves up to 15,000 interruptions, but with 25,000 it is scarcely noticeable, and yet produces a decided sedative effect. Rapidity of interruption, while strongly influencing the physiological effect of the induced current, does not in itself control this as completely as it does when combined with the proper quantity and quality of current and surface-resistance; that is, with suitable coil and electrode, each in itself influencing the nature of the current in a similar manner and approximating the same results.

In brief, I may say, of the contact-breaker, that the physiological effect of the current slowly but distinctly increases with the number of interruptions, from 1 up to 2500 or 3000 per minute; if the current be a mild one, it reaches its highest intensity at 3000 to 4000, then decreases, at about the same rate, until no longer felt with from 7000 to 9000 interruptions. The muscles respond less acutely than do the nerves; very slow interruption, of moderate current, is perceived by the sensory nerves only; as rapidity increases muscular fibre contracts; with greatly-increased rapidity the muscle ceases to respond, and finally the sensory nerves; so that with great rapidity the current is no longer perceived, and yet physiological effects are produced, though the current is *not felt.* The greater the current-strength, the greater the number of interruptions necessary to completely annul its effect. Slow interruption favors muscle-contraction and rapid interruption nerve effects; the very rapid, whether perceived or not by the sensory nerves, is sedative in its action.

Surface-resistance, as produced by character and material of electrodes and moisture or dryness of skin, determines intensity, also quality and effect, of the current, the latter being the important therapeutic factor: moist electrodes, low surface-resistance, render the current painless and penetrating without effect upon the superficial sensory nerves, yet acting with energy upon deep-seated muscles; the cotton-covered electrode, thoroughly saturated with fluid, reduces both surface- and tissue- resistance; the dry epidermis is saturated, its conducting powers

greatly increased, and its resistance reduced; perfect contact is established, the entire surface of the electrode is available, thus lessening the density of the current to a minimum, rendering it painless and causing it to penetrate; the same current, from the same coil, might be arrested upon the surface with revulsive effect, causing great pain in the superficial sensory nerves. This radical change in the physiological effect of the current is produced by a diminution of surface-resistance, the highest resistance, a painful surface-current, being produced by the dry metallic electrode placed loosely upon the skin, the smoothest penetrating current by the moist electrode pressed firmly against it.

A secondary coil of 32 wire, with 4500 feet, 747 ohms resistance, and a current of 400 milliampères, applied with *high* surface-resistance, small metal electrodes, to the middle of upper and lower arm, 500 interruptions per minute, is intensely painful at 50 of the scale, so much so that it could not be borne stronger; applied in the same place with *low* surface-resistance, by the moist electrodes, two inches square, even with the utmost intensity of current, with coils overlapping, at 100, strong contractions were produced, but no pain. The metal electrode with this coil at 50, half in, powerfully affects the sensory nerves, motor nerves barely responding, whilst the moist electrode is hardly perceived under these conditions; and if the current is increased by the moving forward of the coil to 100, strong muscular contractions are produced, but still the sensory nerves are little affected. Thus, it is evident that surface-resistance, character of electrode, and method of application vary the physiological effect of the current, as Duchenne has long since taught. A revulsive effect is produced by high resistance, dry skin, and metallic electrode, whilst the penetrating, deep nerve and muscle effects are from moist electrodes, with low resistance; especially quality and physiological effect is altered by variation of surface-resistance, quantity and galvanometric measure being less affected. The primary electro-motor force unchanged, we vary the intensity of the induction current by the sledge movement of the secondary coil, and its quality, or physiological effect, by variations in the character of the secondary coil, in the number of interruptions, and in the amount of surface-resistance, as determined by character of electrodes, never relying upon any single one of these factors, but combining these various methods of current-variation to achieve the desired result.

V. MEASURE AND RECORD.

The absence of definite galvanometric measure is another of the unfavorable conditions which have served to retard the therapeutic use of faradism. As the study of the induction current by the galvanometer affords no indication of its physiological action, and as up to the present time we have no means of determining a unit of physiological efficiency, we must content ourselves, for purposes of measure and of record, by

defining the conditions under which the current has been developed, and the manner of its application.

It is impossible to compare satisfactorily currents from all medical instruments, by reason of the great difference in construction, especially those in which gradation is one of physiological effect only, without change in any measurable quantity. Uniformity of record and a definition of current-strength can be attained only in the sledge instrument, in which the galvanometer effect, like the physiological, decreases with the removal of the secondary coil from the primary, and the extent of separation of the coils is an approximate gradation; hence, I shall consider only currents from instruments of this kind, which are in every way superior for medical purposes.

The measurable element in the induced current is its *quantity ;* we cannot properly speak of its intensity, nor can we value it in ampères; we can estimate only its quantity, the product of time and intensity ($Q = I \times T$), which is expressed in *micro-coulombs* and is measurable. The same is true of the condenser discharge, as we may see by the experiments of Edelmann, who finds a condenser discharge of 9.8 volts in 261 millionths of a second as effective, physiologically, as one of 70 volts in 70 millionths of a second of time, the increase in time serving to make 9.8 volts as effective as 70; but peculiar difficulties likewise oppose the measurement of this form of electricity, as volt-force is lost when passing off under low potential, the more being lost the lower the potential.

The opening faradic current is measured by sending it into an electro-dynamometer and noting the maximum deviation given by this impulse to the needle, then comparing this with the discharge of a condenser of one micro-farad capacity, charged to the potential of 1 volt, therefore containing one micro-coulomb, which, upon my instrument, is 3.95 divisions of the scale. To measure a given induction flow the shock of the opening current, obtained by pressure upon the single-impulse key, is conveyed to the electro-dynamometer, and the number of degrees obtained, as marked by the greatest deviation of the needle, is divided by 3.95, the product being the number of micro-coulombs, or the current quantity. We can now indicate the galvanometric value, by noting the quantity of the opening impulse in micro-coulombs upon the scale for every change of position of the coil—this being true for a fixed inducing current—for one given coil and for a certain resistance. Moreover, it is necessary that every opening impulse be alike, which is possible only by an even-working contact-breaker, as it is made, but not found in the average instrument for the more-rapid interruptions.

The scale so graded as to indicate in micro-coulombs the quantity of current for a certain resistance is, at present, our nearest approach to measure; and this resistance must be a body resistance, as the current-energy varies differently for metallic and for body resistance ; the maxi-

mum intensity for metallic resistance being attained at 0 or complete overlapping of coils, and at 3 centimetres for body resistance. Even with attention to these details this is deceptive and the scale only an illusory one, as the physiological effect varies with conditions ever present in therapeutic applications, which in no way affect quantity.

Granting that the inducing current remains unchanged, the physiological effect varies with the resistance of the circuit and its variable elements, these being the metallic resistance within the coils themselves dependent upon length and thickness of wire, and the external resistance, size and character of electrodes and body resistance proper, in itself a most unstable element, varying for opening and closing current, varying for different points of the scale, and varying from one moment to the other with the change of potential.

A single experiment will illustrate the extreme variation of current-strength and effect caused by change of resistance, and also the variation of that resistance by apparently trifling causes. Coil I, 0.85 ohm resistance, 528 winds, with an inducing current of 400 milliampères and 5 volts, applied by metallic electrodes, 2 centimetres in diameter, to right shoulder and calf of left leg, with dry skin, presenting a body-resistance of 50,000 ohms, is hardly felt at 100 or complete overlapping of coils; the electrodes are held in place by a spring, pressing them down firmly; the surface becomes red, congested, and moist, so that within ten minutes, without change of any kind, leaving electrodes in place, the current is distinctly felt at both anode and cathode at 47 of the scale, less by over one-half, and is almost unbearable at 100, where but a few moments ago it was barely perceptible. This remarkable change of current effect is caused by reduction of surface-resistance, due to thinning of the skin by compression, and its saturation with moisture by perspiration through prevented evaporation and congestion of vessels. If we now reduce the resistance still more, to 3000 ohms, and apply the same current, through large moist electrodes, three by four inches, to upper and lower arm, we find muscular contraction at 27 of the scale at 100 interruptions per minute, at 29 with 6000 interruptions, but no sensation, and at 47 powerful contractions, without effect upon the sensory nerves; and this coarse coil of 0.85 ohm resistance predominates over the fine coil, 40 wire, 180 ohms resistance, 528 winds, which with high resistance gave far the stronger current.

The experiment is instructive in many ways, but here cited especially to demonstrate the variation of resistance within a few minutes, without change of any kind by the operator, the electrodes even remaining in precisely the same place. More striking still are the greater physiological effects of currents of small quantity and low tension over currents of great quantity and high tension: the latter from a fine coil of 6500 winds, with a primary force of 300 milliampères, 5 volts, 5000 interruptions, and 13 micro-coulombs of opening impulse, produced only a distinct jerk with

no disagreeable sensations, whilst the heavy coil, with 528 windings and less than 4 micro-coulombs, produced strong and painful contractions. This is with low resistance, under the less-frequent conditions of application: the opposite effect would be observed were the test made with the high resistance generally found in faradic treatment.

This striking result is due (Dubois, Stauffer) to the influence of the extra- or self- induced current of opening, within the secondary coil,

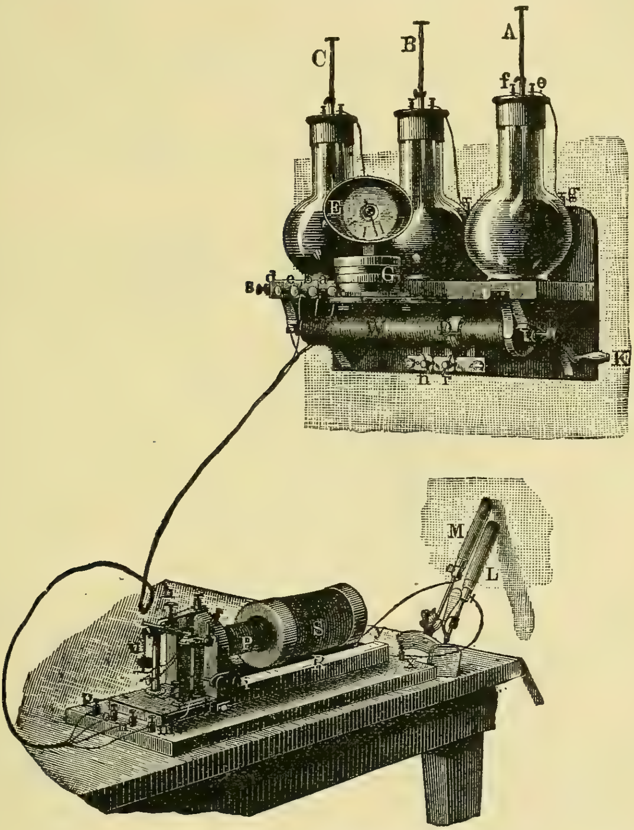


FIG. 6.—EDELMANN FARADIMETER.

upon its own coil-current. The self-induced current is, in opposite direction to the current proper in its own circuit, more effective than the current circulating in a neighboring circuit, and, being in opposite direction, it prolongs the variable stage of the original current which establishes it, prolonging its duration at the expense of its tension, without altering quantity or galvanometric measure; as these self-induction effects increase with the number of windings and the thinness of the wire, the co-efficient of self-induction is much higher for the fine coil, and the current is counteracted far more than in the coarse coil,

being practically 0 in Coil I (Engelmann), 0.8 ohm resistance; hence its greater maximum intensity with less quantity and greater physiological effect on nerve and muscle.

Even less indicative of physiological effect than the gradation of the scale in micro-coulombs is that of the Edelmann faradimeter (Fig. 6) in volts, which is only for a given coil, with a given inducing flow on short circuit, but fails when body-resistance is interposed. The instrument consists of two parts: the stand with the Grenet cells, *C*, *B*, and *A*, with rheostat, *W* and *D*, and galvanometer, *G*, attached to the wall, and the faradic apparatus some distance away, in order that the galvanometer may be removed from the magnetic influence of the iron core within the primary coil. The cell *C* supplies the motive power for the current-interrupter independent of *B* and *A*, which give the current for

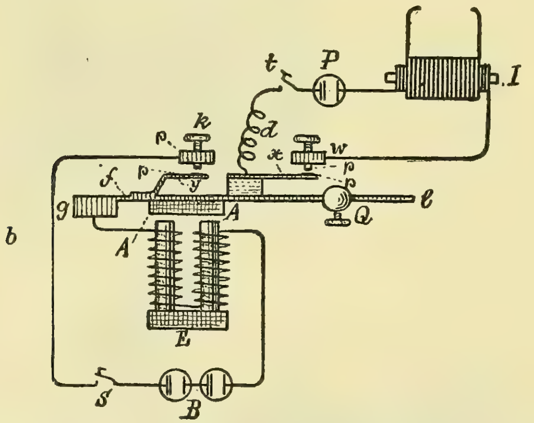


FIG. 7.—COURSE OF CURRENT IN EDELMANN FARADIMETER AND IN MY INSTRUMENT, WITH SEPARATION OF COIL AND INTERRUPTER.

P, battery for coil; *I*, coil; *E*, hammer-magnet; *B*, battery for hammer.

the coils; this primary current must be one of 300 milliampères, in order that the position of the secondary coil may always indicate the correct volt-force of the secondary induction current, as marked on the scale, *R*, of the sledge.

I use but one Grenet cell, and even this gives a stronger current than necessary, but, by the nickelin-wire rheostat, *W* and *D*, through which it passes, it may be reduced to the necessary intensity of 300 milliampères, which is verified by the galvanometer, *G*, through which the current may be sent at will by pressure on the spring-head, *S*, now and then during the *séance*. The force of the primary flow is controlled by testing the galvanometric effect.

Fig. 7 shows the current interrupted by a separate and distinct vibrator as it is in the Edelmann faradimeter, in my new instrument, and as it should be in every accurate instrument for medical work.

The cut (from Edelmann) likewise shows the hammer of Wagner-Neff clearly as an individual feature, propelled by its own separate battery power, whilst usually it is acted by the coil current. *P* is the battery supplying the current for the coil, *I;* the circuit is closed at *t* and interrupted at *p* and *p* by the hammer of Neff. The hammer, or trembler, itself is operated by the battery, *B*, from which the current passes through the electro-magnet, *E*, then to the anchor or bar of the trembler, *A*, and the spring, *y*, which makes and breaks contact with the governing screw, *k*, the spring being set so that contact is established at *p* and *p* when no current passes. As soon as a current is established by closing the circuit by the key, *S*, the soft-iron horseshoe magnet, *E*, is magnetized, acts as an electro-magnet, and attracts the bar, *A*, breaking the current at *p* and *p;* the current broken, *E* is demagnetized and the trembler, *A*, is released, returns, and re-establishes contact, thus making and breaking the current at both points of contact, *p* and *p*, both for the hammer current and the coil current; yet there is no current connection between these two points, as the contact-breaker for the coil is superimposed upon the bar of the trembler, *A*, but insulated from it, so that the current from *P*—the coil current— is made and broken as often as the trembler, *A*, completes a vibration, yet the currents are separated by the insulating block. My own interrupter differs somewhat from this, and my controllable high-speed contact-breaker is upon an altogether different principle, with this one point of resemblance only,—that the motive power for coil and trembler is separate and distinct, whilst in all other instruments now in use it is one and the same battery-force which supplies both, and contact is made and broken by a spring alternately attached to and flying back from the electro-magnetic coil core as it is magnetized and demagnetized by the make and break of contact.

By the separation of the contact-breaker we avoid loss of power and the self-induction action of the electro-magnet upon the coil current.

The quantity of the current is dependent upon (1) the galvanic inducing flow and primary coil; (2) number of winds of secondary coil and thickness of wire, or coil-resistance; (3) position of coil on sledge; (4) resistance of circuit, but in order to determine therapeutic or physiological effect we must know (5) surface-resistance or character of electrodes and skin; (6) number of interruptions and time of application. The only measure of effect we now have is a record of the details of current production and method of application, and this enables us to value the character, strength, and effect of the faradic current with some degree of precision.

The following points I deem necessary for determination of current effect and for record:—

1. Strength of galvanic inducing current.

2. Character of secondary coil, number of winds, and resistance of coil.

3. Resistance of the circuit, of body, and electrode.

4. Character and size of electrodes determining density of current, pain, and penetrating power.

5. Position of secondary coil on the sledge scale.

6. Number of interruptions of the contact-breaker, approximatively at least, until instruments of precision are furnished.

7. Duration of the *séance*, or time of application.

The first of these, the primary flow, is the only permanent one of the various elements upon which the current effect depends; so that it is evident how difficult it is to obtain a precise estimate of current-energy or physiological effect, since quantity proper, as expressed in micro-coulombs, conveys only a partial and imperfect idea of its value. But, in order to make even this record possible, it is necessary that the manufacturer should construct the apparatus with precision, and that each instrument should carry upon its face an index of force; character of primary coil should be given, and each one of the series of secondary coils must indicate number of winds and resistance of wire; the number of interruptions of the variable contact-breaker, at different points, must be marked; and electrodes should be made in standard sizes, and in proper relation to each other; uniformity in electrodes, primary coil, and galvanic inducing flow would greatly facilitate record and comparison.

VI. EFFECT; METHOD OF ACTION.

The effect of the faradic current upon the human system varies greatly with the character of the current (force of primary flow, nature of coils, and rapidity of interruption), the nature and size of electrodes, and the resistance offered by the body itself; in general, I may say that its action is either irritating and stimulating or sedative, contracting or relaxing, and that this effect of the current, upon any part or organ of the body, is produced by its action upon the controlling nerves and muscles; but in what manner the effect is exercised I cannot positively say. This is as yet an unexplored field. The mechanical action seems prominent; whether or not it acts in other ways as well I am not prepared to state with any degree of certainty. We know that the faradic current can produce chemical changes, as is proven by the spark and its action even upon the invulnerable platinum; but as the polarity is constantly changing, the action of one current is counteracted by that of the next, so that the effect can be but momentary, and nascent chemical products rarely combine; so that a permanent effect can hardly be attained. The chemical effects produced are greatest in currents of greatest quantity from heavy, short, secondary coils, and of slow interruption, becoming quite marked when the closing current is eliminated, as in the one-direction current of the Stöhrer instrument, and likewise in the primary circuit. I do not believe that the chemical effect takes any part

in the action of the faradic current upon the system, but that this is a certain mechanical influence upon the molecular composition of the organism, prominent in its dynamic action (Stein). Boudet cured facial neuralgia by the vibrations of a tuning-fork, 200 per second, communicated to a sounding-board, upon which was fixed a small rod with ball end, which was placed upon the face at the point of exit of the infra-orbital nerve, thus communicating the vibrations to that nerve; after an application of from five to six minutes the pain ceased for a time, and by continuation of the treatment a permanent cure was achieved. I do not rely upon the one statement, but find this indication of the curative therapeutic effect of mechanical vibrations corroborated by the experience of others both in England and in France, and quite recently Charcot's investigations have given a renewed impulse to this medicine *vibratoire:* in the Salpêtrière a large tuning-fork, placed upon an extensive sounding-box, was used, the atmospheric vibrations produced thereby acting as did the rod in the other case, and with similar satisfactory results, even to the restoration of muscular activity in the paralyzed lower arm of a hemianæsthetic.

I fully agree with Stein, who believes that in the mechanical vibratory action of the faradic current we must seek the cause of its physiological action; but as to the idea expressed, that many electro-therapeutic effects are due to a regulation of molecular vibrations, I can say nothing. The question is still an open one, and must be solved ere faradism can be accorded its proper place in medical therapeutics.

C. Medical Uses.

Faradic electricity is used in medicine for purposes (1) of *diagnosis* and (2) of *treatment*, but the range of its utility has been limited by reason of the prevalence of galvanism, our limited knowledge of faradism, the absence of measure and means of comparison, and largely by the crudeness of the instruments furnished, which give but a certain form of induction current, to which therapeutic applications must, of course, be confined, making it really useful in a comparatively small number of cases only. It is impossible to compare galvanic and faradic currents as therapeutic agents, as each has its proper sphere, and that of the induced current will be greatly enlarged with increased knowledge and greater precision and variation of current.

We speak of the positive pole as the anode and the negative as the cathode, which may always be recognized by its sharper current and greater effect on motor and sensory nerves. The prevalence of the negative over the positive pole is more marked for short, heavy coils than for long, fine coils, and likewise more marked when applied through low resistance than through high resistance. Using Coil I,[1]

[1] In speaking of Coil I, II, or III, I always refer to the standard coils of my apparatus as manufactured by Waite & Bartlett, because these are the only coils which are precise as to quantity and quality; number of winds, resistance, length and diameter of wire being noted.

with low resistance, 2500 ohms, both hands in warm zinc-water, 4000 interruptions per minute, the negative pole is first felt at 25 of the scale and the positive at 31; the first contraction is secured by the negative at 44 and by the positive at 50. With Coil III, 1500 feet, and the same conditions, the first sensation is observed at 12 at the negative pole and at 21 at the positive, the first contraction at the negative pole at 26 and at the positive at 31. If we take a high resistance, though only 5400 ohms, we find less difference in positive and negative for Coil I, and with Coil III, 1500 feet, the negative pole is first felt at 22 and the positive at 23, the first contraction or muscle-jerk, for both positive and negative, being noted at 31, whilst for Coil III, 4500 feet, positive and negative vary even less.

I. DIAGNOSTIC USES.

The faradic current is valuable diagnostically for determining the existence, the increase or decrease of pathological excitability, in differentiating between central and peripheral lesions, and in the detection of simulation. In gynæcological practice it is of prominent diagnostic import in differentiating between abdominal and more especially ovarian pains of an hysterical and those of an inflammatory character. The fine coil or tension current with its sedative influence has a potent calming effect on hysterical suffering, especially in abdominal and ovarian regions, and serves an admirable purpose in differentiating between nervous or hysterical pains of the ovary and those which are inflammatory; this means of differentiation, recently emphasized by Apostoli, should be more frequently resorted to, as many a patient is subjected to operation for ovarian pain of a purely hysterical nature, which would have been detected and relieved by the faradic current, had it been properly tested.

In faradic exploration a careful comparison must be made between the healthy and diseased side, or, what is less advantageous, between the part in the diseased and the same part in a healthy person, and repeated investigations are necessary before a positive result can be reached. For scientific exploration we must know the resistance of the tissues on either side, size and resistance of electrodes, number of interruptions, and character of coil and current-strength,—which we are as yet unable to give, but which, for purposes of record and comparison in one and the same case, the primary-battery flow remaining unchanged, is indicated by the relative position of the coil on the sledge scale. The irritability of the muscle is tested by determining the lowest power of the faradic current which will contract it, and then comparing this with the healthy side. It may be noted that in hysterical paralysis electro-contractility is generally normal while electro-sensibility is lowered, and in infantile paralysis voluntary contractility is increased whilst faradic contractility disappears; so also in the reaction of degeneration, or when by an injury,

a cut severing its continuity, the nerve is destroyed, and more or less atrophy or degeneration is found in both muscle and nerve. Even with the crude instruments of former days the variability of reaction in healthy and diseased tissues was well characterized and the faradic current a valuable diagnostic agent; so that we may now expect still more from this current, so thoroughly controllable as it is by the new apparatus.

II. THERAPEUTIC USES.

Even in the secondary position still occupied by faradism it has a broad range of application in medicine and is used in a variety of ways: (*a*) applied to the body direct; (*b*) in faradic massage; (*c*) in the faradic bath.

(*a*) *The direct application of the current*, with both poles in contact with the body, is the usual method of therapeutic use of induction currents, as general, as localized or polar, and as bipolar faradization.

General Faradization.—The labile application, over the entire surface of the body, so earnestly advocated by Rockwell, is used as tonic and stimulant in constitutional debility; above all, in nerve-exhaustion, and as a powerful irritant in cases of asphyxia, suspended animation, and poisoning.

Localized faradization, as Duchenne termed this new departure in electro-therapeutics, the application of the current by one pole direct to the part to be affected, is the method most generally used, and should more correctly be spoken of as *polar* faradization, in contradistinction to the bipolar method and the polar method of galvanization, which is precisely the same manner of application in the use of the galvanic current. This localized or polar method of application has done away with the former distinction between ascending and descending currents; but we still speak of labile and stabile currents, one of the electrodes being moved over the surface, or both stationary, and of superficial and deep, or penetrating, currents,—the former with the dry metallic electrode to the dry skin and superficial nerves, the latter with moist electrodes to the deep-seated tissues. These are the ordinary methods of its therapeutic use: as nerve and muscle irritants in all kinds of paralyses, heart-weakness from various forms of poison, as stimulant in cases of constipation, vesical weakness or relaxation of nerve- or muscle- fibre in any part, and as sedative in neuralgias, in hysterical and inflammatory pains; the short coil of fine wire serving as the most powerful irritant with the dry electrode, the long coil of fine wire having the greatest penetrating power, and with very rapid interruption of current the most marked sedative effect, readily producing tolerance and a certain amount of anæsthesia. The short coil of heavy wire, with slow interruption, produces the most effective muscular contractions, but, instead of producing tolerance, seems to render the tissues more susceptible.

The Bipolar Method.—The bipolar method is the localization of the

current by means of a single electrode carrying both poles, and has of late assumed prominence by reason of the able and energetic work of Apostoli and the efficiency of the methods devised by him in uterine and pelvic disease. It is restricted almost wholly in use to the inner parts, the cavities and mucous membranes, and is practically the application of localized electrization to internal organs; since the current, to be localized or confined to these parts, must of necessity be applied by means of a single electrode; as so little space is given, a metallic rheophore only is admissible, and this can be used effectively for penetrating currents on the mucous membranes, which offer a very low resistance, not to be compared to that of the dry skin, and for this reason, as well as the absence of the numerous sensory nerves, it causes much less pain than would a metallic electrode upon the skin,—indeed, no pain at all. Currents of quantity for muscle effects, and currents of tension as nerve stimulant or sedative, can both be used to advantage, and without causing pain.

Our knowledge of faradic electricity and the means of varying and of applying the current have improved so that the principle long upheld, that for external faradization currents of tension are most active and that in internal, bipolar or localized, faradization the current of quantity acts most vigorously, can no longer be followed as a fundamental rule. Although it is true that currents of high tension penetrate deeper where the resistance is great, as upon the skin, and that the current of quantity is strongest if the resistance is very low, yet it is wrong to generalize and to refer the current of tension to external and the current of quantity to internal faradization. Some of the best therapeutic effects of tension currents, such as the relief of ovarian and pelvic pains, are achieved by their internal use, and equally striking results of quantity, or coarse-coil currents, are obtained in external application, as for purposes of massage or direct muscular contraction.

The advantages claimed by Apostoli for the bipolar method in internal applications are (1) that it is more simple, requiring no assistant; (2) that it is less painful, the sensitive skin being avoided; (3) that it is more active, as localizing the full effect of the current used upon one small part; (4) that it is more efficient, as it admits of the use of stronger currents by reason of the lessened sensibility.

(*b*) *Faradic Massage.*—Under this term, which I look upon as a misnomer as it is now used, is generally understood the combination of faradization with massage: the heightening of the stimulating or sedative effect of massage by a corresponding faradic current applied by means of the same apparatus by which the mechanical effect is exercised upon the tissues, be it hand, or plate, or roller electrode. This I should call a combination of massage and faradization, whilst I term faradic massage proper the stimulating or contracting of the muscle by faradic currents of quantity and slow interruption,—the most efficient of all means of muscular stimulation or massage, as it can be applied directly to any desired muscle

or group of muscles, and stimulates the tissues by arousing heightened natural action.

I will not elaborate this now, but will speak merely of faradic massage as generally understood, a most agreeable and effective method of treatment. The effect of massage, which has been established in our country by the earnest efforts of our honored colleague, Dr. S. Weir Mitchell, and his successful treatment of neurotic, bedridden women, is increased by the use of a properly-modified current, galvanic or faradic, as the case may be. Thus, the absorbing action of the hot baths of Hot Springs or of Wiesbaden is heightened by galvanic massage, and the sedative and stimulating action of tonic waters or treatment by faradic massage.

The *galvanic* current *alone* causes a more permanent hyperæmia without the disadvantage of the mechanical irritation of massage, and, on the other hand, it lacks the advantages of the mechanical effect,—the removal of stagnating blood and lymph; both together, properly applied, re-inforce each other, the galvanic current making the effects of massage more lasting. The rules for application are the same as for simple massage. The method of action is well stated by Mordhurst as follows: (1) the hyperæmia caused by massage is heightened and prolonged by the contemporaneous application of galvanism, and this heightened effect is achieved without the injurious influence of too intense mechanical irritation, as severe and long-continued massage would produce it; (2) by massage with the massage electrode the absorbed particles of the pathological product, taken up by the lymphatics, are mechanically removed from the diseased site; (3) the long-persisting hyperæmia in the skin aids greatly in the depleting of the morbidly-affected lymphatics in the neighboring tissues.

Galvanic massage is especially adapted for the treatment of articular rheumatism and the removal of indurations and inspissated deposits, but it is also used for the relief of neurasthenia and neuralgic pains.

Faradic massage augments the stimulating effect of massage, and by the penetrating powers of the current extends its range of action to the deeper tissues, without adding to the superficial irritation; the calming, sedative effect of the mechanical manipulation is likewise increased by the direct action of tension currents upon the nerve-fibres. Faradic massage is useful in various forms of nerve-exhaustion, neuralgias and headaches, in chlorosis, in paralysis, constipation, muscular rheumatism, and in certain phases of chronic articular rheumatism. Although generally applied by a current from the ordinary battery, by means of the plate or roller massage electrode, Butler uses an apparatus of his own construction, in which the generator is within the roller itself.

(*c*) *The Faradic Bath and Douche.*—Both faradic and galvanic currents are used in hydro-therapeutic treatment, and are combined with

bath or douche, as the electric bath and the electric douche, and are used in very much the same class of cases as electric massage, though more general in its effect. The manner in which the bath is given varies with the construction of the tub, whether this is of a conducting material or not. If the tub is of metal, generally copper, the patient must be protected from contact with its walls by a lath-work of wood : one rheophore is connected with the tub itself, and the current is thus carried by the water to that part of the body which is immersed, the other electrode being applied to a part out of the water. More commonly a tub of non-conducting material is used; porcelain is best, but wood, coated with white, non-metallic enamel, can be used, and is cheaper. The current is generally passed lengthwise through the body, the back or shoulders resting upon the non-conducting protector of the one plate and the feet against the other; some use a larger plate at the head end, but others (Trautwein) merely coil the terminal of the battery-wire a few times in this electrode and use a large plate at the foot end; for some conditions the current is directed more to certain parts by small plates placed accordingly. Back and feet rest against the protecting, non-conducting rim of the electrode, about one and a half inches from the plate itself; it should not be too far away, in order not to diffuse and weaken the current, as water, unless very warm, opposes far more resistance to the current than does the body. The resistance of water as pleasant for a warm bath is but a trifle greater than that of the body with the epidermis saturated, and at 30° R., or 38° C., a hot bath, the resistance of water and body is the same; so that the current-measure is the same, whether passing in the bath through the water alone, or through water and body in the tub.

It is said that about one-sixth of the current passes through the patient (Steavenson), the saturation of the epidermis diminishing the resistance greatly, so that from a galvanic current of 200 milliampères the patient receives 40 milliampères. This diminution of resistance, which is, of course, readily shown by actual measurement, is further marked by the equality of closing and opening induction current in the faradic bath, and by the inefficiency of tension currents from fine secondary coils, which have almost no effect; hence the primary coil is used for bath currents, or, better still, secondary coils of very heavy wire.

The important features in determining the result are: temperature of bath, kind and intensity of current, and time of application. Plain water is used, to which solutions are often added, but the mineral waters of health resorts are preferable. From ten to fifteen minutes is amply long for a first bath; this is increased in time with the staying powers of the patient, but should rarely exceed thirty minutes. It is well to begin with the body temperature of 98° F., gradually increasing or decreasing as the case may demand. The strength of the current used will depend upon the necessities of the case, but, as the time of application

is prolonged, it should never be very strong; the faradic current must, however, be distinctly felt, and the galvanometer must be consulted for the galvanic bath, as with the diminution of surface or skin resistance, and the large surface of application, low density of current, it may produce but little sensation, yet a powerful constitutional effect.

The *faradic bath* is the perfection of general faradization and the direct opposite of localized electrization, the confining of the effect to the diseased part; as it is frequently used to intensify the action of curative mineral waters, it is found in its greatest perfection in watering places; the faradic current, thus used, in combination with a bath of proper temperature, is a most agreeable sedative in neurotic cases, and a pleasant as well as efficient stimulant in general debility, as from anæmia or neurasthenia, and it is most unfortunate that this useful agent should be more or less relegated to quackery. In place of being conscientiously applied by skilled hands, under proper conditions, we find it in public establishments, handled by an ignorant attendant, and given to whomsoever pays for it, or, worse still, it is a money-making agent for the advertising quack. In many instances the effect is, of course, pleasant and satisfactory; but if the patient be sensitive, or the case one contra-indicating the bath or the current, the innocent seeker after health may be carried away unconscious, or may receive a shock from which it will take him or her days to recover. This useful remedy should be developed, and restored to the realms of legitimate medicine.

The *faradic douche* is an equally valuable agent in its proper sphere, as a general application, in neurasthenic cases, and locally used in uterine and spinal diseases. The douche proper, hot or cold, is used as the rheophore, or conductor, to carry the faradic current, by which its efficiency is greatly augmented: A large plate electrode is applied as the indifferent pole to a near surface of the body, and douche or spray, of proper temperature, is thrown from the fluid-carrying rheophore, at a distance of six to twelve inches, upon the part to be reached. It is an admirable application in spinal weakness, and as a sequence to the bath, or alone, in neurasthenic cases, producing a pleasant tingling feeling and a healthy reaction; so also the cold spinal douche is given in or after the hot bath, and the tonic and astringent effects of the uterine douche can thus be augmented by the faradic current.

III. APPARATUS FOR THE PRODUCTION OF FARADIC CURRENTS FOR MEDICAL PURPOSES.

A. Essential Features of the Apparatus.

The elements necessary for the production of faradic currents are (*a*) a flow of galvanic force; (*b*) the primary circuit or coil; (*c*) the strengthening core; (*d*) the automatic interrupter; (*e*) the secondary

circuit or coil; (*f*) an appliance to vary the current-strength without change in the flow of galvanic force.

I. THE GALVANIC INDUCING FORCE.

Galvanic currents of small quantity and low tension are used in the production of faradic electricity, averaging from $1\frac{1}{2}$ to 5 volts and from 200 to 1500 milliampères, those of highest ampèrage having the lowest voltage and *vice versâ*, the Leclanché cells with lower ampèrage having a higher voltage. The current-producers vary with the instrument. Those most commonly used are (*a*) the sulphate of the binoxide of mercury cell, which is extremely convenient for the pocket-battery, as the dry powder, being in small bulk, can be readily carried about in a bottle within the battery itself. The carbon forms the receiver or cup within which the salt is dissolved in a little water, the zinc being placed into it after stirring; a single charge gives a flow of force sufficient to supply the instrument for the longest *séance*. (*b*) The small bichromate of potash cell: either upon the principle of the Grenet cell, or, as it is frequently used in the portable box-battery, carbon and zinc in one cup and the fluid in a second, well sealed with a rubber cork, so that it can be poured into the empty cell when it is to be utilized. For the stationary or sledge instruments we generally use (*c*) the Grenet cell, giving a current of $1\frac{3}{5}$ volts and $1\frac{1}{2}$ to $2\frac{1}{2}$ ampères, which is convenient, as it is ready for use as soon as the zinc is dropped into the fluid; but objectionable on account of the acids employed, the fluid being a solution of bichromate of potash and sulphuric acid. Preferable is (*d*) a couple of two Leclanché cells, in which the harmless muriate of ammonia filling needs but the addition of a little water once or twice in a year, if evaporation is prevented by a well-fitting cover. Sometimes three or four are used (two suffice for many purposes for some instruments), giving a current of about $2\frac{2}{3}$ volts and 250 milliampères.

The Gonda-Leclanché or the permanganate of potash cell—in fact, any couple of one of the numerous similar elements, with harmless fluid and cover to prevent evaporation—is most suitable, as the current is established as soon as the circuit is completed, the apparatus being set in motion by a turn of the switch.

II. THE PRIMARY CIRCUIT.

The primary circuit, always stationary, is, as we have seen, a solenoid consisting of a number of turns of well-insulated copper wire, wound in regular layers upon a hollow cylinder of non-conducting material, wood or hard rubber, with the zinc connection inside of the coil. Wire of moderate thickness and length is used, frequently No. 22 wire, 0.7 millimetre in diameter, so that as little resistance as possible is opposed by the conductor itself to the primary galvanic flow; and yet it

must admit of sufficient electro-motive force to push the current through the long secondary coil; though it cannot be too thick, so as not to occupy too much space. This primary coil must be proportionate to the battery-force employed; the magnetism produced by the solenoid in the core being proportionate, as long as the customary small magnetizing force is employed, to the intensity of current and the number of windings of wire; but after a certain force is reached the increase in magnetism becomes less marked and tends more and more to a limiting value, which is greater for soft than for hard iron or steel.

Too many windings or lines of force render the instrument bulky and decrease its power. The large sledge instruments of Edelmann and Waite & Bartlett have a primary coil of 22 wire (0.7 millimetre in diameter) in from 4 to 6 layers, with from 200 to 400 turns; smaller instruments are made with coils of fewer turns and often thicker wire, giving a sharper current. The large instrument of Gaiffe has a primary coil of 0.7 millimetre wire with 1150 turns, forming a spool 19.7 centimetres in length by 3.8 centimetres in diameter,—shorter than that of Edelmann and longer than that of Waite & Bartlett. This circuit is always closed unless opened by the interrupter; but if the primary or direct extra-current is to be utilized, it is switched off at the extremities of the coil to two binding-posts, from which it is taken, thus forming a branch circuit which is generally open, and closed only by the object through which the primary current is passed, when this is to be utilized.

III. THE CORE.

The strengthening magnetic core, by which the magnetic force of the surrounding solenoid is increased, depends for its efficiency upon its conductivity; that is, the rapidity with which it is magnetized and demagnetized, the rapidity of variation or change of potential determining the physiological efficiency of the current produced.

A bar of soft iron was placed within the hollow of the primary cylinder, projecting a little at either end, beyond the cavity of the spool; soft, well-heated iron was employed, as this material is magnetized and demagnetized most readily; yet disturbing induction processes, or eddy currents, were found to take place within its mass, which led to a loss of power, so that it was supplanted by bundles of well-heated soft-iron rods carefully insulated. Spirals of wire are also used; and the core of the Engelmann instrument consists of a sheet of soft iron, as thin as paper, rolled into a cylinder, which seems to magnetize and demagnetize more readily, and also to give a more satisfactory physiological effect than the wire core. This core may be fixed or movable, made so as to be wholly or partially withdrawn, or it may be covered by a movable copper or brass tube. This brass or copper cylinder, *the tube of Duchenne*, made to slide between core and primary coil in the pocket-battery, and between primary and secondary coil if used in a sledge instrument,

but, as a rule, found only in small instruments of simple construction, is used to vary the strength of the current. The method is simple, yet unsatisfactory, as the presence or withdrawal of the tube weakens or strengthens the physiological effect of the induced current without changing its quantity, and weakens it but imperfectly.

The presence of this tube acts as a damper on the magnetic forceps of the core by interfering with the lines of force from the coil to the iron core by counter-currents which they themselves produce in the cylinder, and thus the opening or break current is modified in its intensity. With the opening of the current in the primary coil two currents are induced, one in the coppér cylinder and one in the secondary coil; both have the same direction and induce in the other conductor a current contrary to the first; the result is that the induced current is hindered in its ascent, the curve is flattened, its physiological effect is diminished, although its galvanometric quantity remains unchanged.

IV. THE INTERRUPTER.

(*a*) *Importance.*—The current-breaker, interrupter, trembler, vibrator, or hammer, as still made in the great majority of medical instruments, is merely the automatic arrangement by which the changes of potential in the galvanic flow, which develop the induction current, are produced in rapid succession, without manual interference, by the successive making and breaking or closing and opening of the primary current, and all that is required of it is a uniformity of action, as indicated by a "clear note" or a smoothly buzzing sound; yet this mechanism—upon which the very being of the faradic current is based—is one of the most important factors of a serviceable faradic apparatus, as, by a variation in its action, all other conditions, such as battery-current and position of coil, remaining the same, the character of the current is changed and its intensity or physiological effect can be varied from a minimum to a maximum intensity by variation in time and phase of the rise and fall of the potential, and also by the rapidity with which rise and fall of like phase succeed each other. In the primitive state in which it is found in most medical instruments it is deprived of all significance but that of a simple interrupter and maker of induction force, all that is demanded of it being that it "do not make a rasping noise or act irregularly."

(*b*) *Number of Interruptions.*—The interrupter as generally made vibrates between thirty and fifty times in the second,—that is, at the highest, about 3000 per minute,—and thus serves to establish an induced current of a certain quality; but as its physiological effect is varied by number and character of these interruptions, and a single trembler rarely admits of sufficient variation, one or more interrupters are attached to the more perfect instruments.

The most satisfactory arrangement we have had is that by which the character of the interruptions can be varied and their number changed at

will: this is attained to a certain degree in the Waite & Bartlett instrument with two interrupters, from 1 to 50 or 60 per second, and in the Gaiffe instrument, with one trembler, only up to 50 per second,[1] and by the single impulse-key, with which each of these instruments is supplied, they can be made at will, by manual pressure, in very slow succession. Simple as this appliance is, and important as it is for purposes of diagnosis and muscular massage or stimulation, it is not found in the average medical instrument.

I regret that space does not permit my entering more fully upon this subject, as my recent experiments demonstrate most unquestionably that the interrupter is one of the most valuable factors in current control and variation, and that the range and utility of the faradic current will be greatly enlarged when instruments with properly-variable tremblers or interrupters are given to the profession; and these must be such that they can be set at will from one to many hundreds per second, must be entirely independent of the galvanic flow which acts the coils, and propelled by a separate and distinct motive power.

(*c*) *Kinds of Interrupters.*—Contact-breakers as now made are of three kinds, (1) the core itself serving as the attracting magnet, or (2) a separate magnet is formed; but in both the battery-current, which serves as inducing force, also determines the magnetizing and demagnetizing of the magnet, which causes the vibration; but (3) in instruments of precision the contact-breaker is an appliance separate and distinct from the induction apparatus, with a motive force independent of that of the instrument proper. I may add (4) the single impulse-key and (5) the rapid controllable interrupter, which must be added to a perfect instrument.

The contact-breaker *in small instruments* and in those of more simple construction consists of a spring with soft-iron hammer-head, platinized, in which the wire of the primary circuit terminates; the force of the spring presses the hammer-head against the other part of the vibrator,—a platinum-pointed screw,—which forms the terminal of the battery wire, thus establishing the flow of force, rendering the core magnetic. The hammer, being placed within the magnetic field, within one-sixth to one-fourth inch from the core, is attracted to this soft-iron terminal, breaking the primary galvanic circuit, whereupon the core is demagnetized, becomes neutral, and releases the spring, which flies back to the battery terminal and the process is repeated. The rapidity of vibration in the average instrument can be regulated, within moderate limits, but not sufficient to determine any marked variation of physiological effect; this is done by the platinum-pointed screw, which controls the length of oscillation by increasing or decreasing the distance

[1] Since writing the above the singing rheotome has been adapted to several instruments and gives vibrations of much greater rapidity; unfortunately, it is not possible to regulate and control these as it is necessary to do for therapeutic purposes, and the vibrations vary with the battery force employed, as the rheotome is not independent of this.

between core, or magnet, and screw-point or battery wire, within which the hammer moves.

In most *larger instruments* of foreign make the attracting force is not the core, but a small electro-magnet entirely independent of it, formed by the coiling of the battery wire around a soft-iron horseshoe; and it is of necessity so, in all instruments in which the battery force is varied by withdrawal of the core, as this must be movable without interfering with the efficiency of the apparatus. This is the ordinary contact-breaker, the hammer of Neef, or Wagner-Neef, which is more or less complicated according to the perfection of the instrument, yet never practically varies the effect of the current. Screw-point and hammer-head are always platinized, in order that oxidation may be prevented and perfect contact may be interfered with as little as possible; the bright spark formed at these points would rapidly destroy other metals, and even the almost invulnerable platinum is gradually coated with a thin film and slowly corroded so that the point of contact must be occasionally changed, and in time, after long use, even the platinum must be replaced. The platinum surface should be cleansed and the delicate film of oxide removed, as it offers a resistance, an obstacle to the passage of the current, which causes loss of power.

Independent Interrupter.—In faradic instruments of precision the motive power for the contact-breaker is supplied by a separate current, independent of that supplying the inducing force: this is a change which I deem important, because I have found that the vibrations of the trembler, in instruments as generally made, are varied by every change in the inducing flow and in the position of the coil, and also on account of the disturbance in the current caused by the self-inductive action of the separate electro-magnet attracting the hammer. In my new instrument, as made by Waite & Bartlett, the inducing current enters the primary circuit directly and is made and broken by the action of the vibrator, which is set in motion by an independent force. This I deem the only method of interruption for a complete instrument, being entirely independent of the coil current proper, as it is acted by its own battery force, and it is a method which can be adapted to every kind of interrupter.

Very slow interruptions are produced by a pressure upon a spring, the single impulse-key, such as is found in the Gaiffe and Waite & Bartlett instruments.[1]

The better instruments are furnished with improved contact-breakers of varying form, some of them having two or three,—rapid, slow, and single impulse,—the slow vibrator varying from 1 to 20 in the second, and the fast spring with from 20 to 60 oscillations per second; the singing rheotome of the Galvano-Faradic and Dry-Cell Battery Company's instrument is a horizontal steel vibrator, far more rapid than the above

[1] Since writing this other instruments have appeared with the single impulse-key, which is a valuable addition.

vibrators when currents of sufficient power are used. Although admitting of rapid vibrations, these vibrations, as already stated, are not sufficiently controllable, and not controllable to a sufficient extent to make this method one which is available for medical instruments of range and precision ; moreover, as considerable battery force is necessary to act this rheotome, the same strong currents which are necessary to act the rheotome must be used for the coil, and mild currents, which are frequently needed in therapeutic applications, are inadmissible.

To attain all the varying physiological effects more rapid contact-breakers, not necessarily vibrators, such as I have suggested and Messrs. Waite & Bartlett have constructed for me, are needed ; these are independent of the primary galvanic flow and controllable, as I consider it to be of great importance that the operator *should know*, approximately, at least, the *number* of interruptions for purposes of scientific research or therapeutic record. The interrupter is arranged so as to indicate, within reasonable limits, the number of oscillations at any given point. This interrupter is a separate instrument, which may serve as interrupter or alternator for galvanic or faradic currents, primary or secondary ; the speed is obtained from the shaft of a motor propelled by a Grenet cell or storage battery, giving 50,000 interruptions per minute, as I believe that 50,000 per minute, 800 per second, is a rapidity sufficient for therapeutic purposes, though I have experimented with interruptions of over 100,000. I have as yet made no therapeutic tests of these highest rates, and have had no more instruments so constructed, as the results of my physiological experiments are such as to lead me to believe, with great assurance, that the most satisfactory therapeutic effects and all necessary current variations are obtainable with interruptions up to 50,000 per minute, and that higher rates are useless unless the make of the induction apparatus is greatly changed ; with instruments as now made 50,000 per minute is an extreme ; any number can, however, be obtained, if desired, and always with precision. The speed indicator, the rheostat, and galvanometer admit of a perfect control of these interruptions.

Observations upon the physiological effect of variable interruption are almost wholly wanting, for the reason that only trifling variations have been achieved by the instruments hitherto furnished, and no index to their number is given, nor can a desired number be attained at will; so that it was simply impossible to record the work done, even within the narrow limits which were allotted. The only method we have had of determining the number of oscillations of the interrupter was by comparing its note, or its musical interval, with the note of a tuning-fork of known vibration, and even this is referred to but rarely, and used more rarely still ; it is practically possible only to the perfectly-trained musical ear. Each octave has twice the number of vibrations as its key-note, the major third $\frac{5}{4}$, the fourth $\frac{4}{3}$, the fifth $\frac{3}{2}$ the number. (Edelmann.)

V. THE SECONDARY CIRCUIT.

The secondary circuit is that from which the alternating, inverse, and direct current, the induced current proper, as generally used in medicine, is taken ; hence it is an important feature of the apparatus. Its force, like that of the primary circuit, is increased by increasing the number of windings, each winding or turn of wire having the same electro-motor force ; so that ten windings possess ten times the electro-motor force of one, and in the completed coil we have the added effect of each single winding or line of force. The quantity of electricity passing is, however, inversely as the resistance offered by these windings, the greater the less the resistance ; that is, the thicker the conducting wire and the shorter it is, or the fewer the windings, the less resistance do they offer. To be most efficient as an induction-current producer, resistance and number of windings must be in proportion to the inducing force, to the galvanic flow, and the magnetic power of primary solenoid and core.

This circuit, like the primary, is constructed of well-insulated copper wire, coiled in regular layers upon a non-conducting hollow reel, conaxial with that of the primary coil, which fits into this hollow. As the strength of the induced current depends upon the nearness of the inducing to the secondary induction circuit, the layers of the secondary winding must be as near as it is possible, without contact, to those of the primary, which must fit closely into the very thin spool of the surrounding secondary coil, and a limit is placed to the number of layers of its windings,—that is, the thickness of the spool ; its length, determining to some extent the approximation of the circuits, likewise influences the nature of the resultant induction current ; but, although long spools have their advantage, they likewise have their disadvantage, and the more smooth and pleasant, yet therapeutically effective, currents are developed from the secondary circuits coiled on shorter spools. This interesting and practically valuable fact I cannot explain, but its truth has been proven by repeated and careful tests of the best instruments, with every possible length of coil. Within certain limits, dependent upon the inducing force, the secondary coil should be constructed, in regard to resistance and number of winds, with a view to the physiological or therapeutic result to be obtained,—a feature which, to the great detriment of faradic electricity, is hardly found in any of our medical instruments.

I am not as yet prepared to define positively the most efficient forms of secondary coil for our various therapeutic needs, and will merely say that I am now testing coils constructed in reference to the instrument with which they are to be used, varying in resistance from 0.8 ohm up to as high as 2500 ohms, and in number of windings from 528 to 12,000, with wire from No. 15 to No. 36 and 40,—the finest which can be well insulated.

VI. METHODS OF VARYING STRENGTH OR INTENSITY OF PHYSIOLOGICAL EFFECT.

Every apparatus for the production of faradic electricity must be provided with some means of varying the current-strength without altering the primary galvanic force. The *direct*, *primary* or extra, current is weakened by the withdrawal of the intensifying core, or by a decrease of magnetizing power by the presence of the shielding tube; so that these parts are arranged to be withdrawn or inserted at will; yet many instruments are void of any such mechanism, as they ignore the utilization of the primary current.

The essential feature is the *gradation of the induced* current, and this variation of the electro-motor force in the secondary coil is attained without change in the primary flow by varying the coefficient of mutual induction of the circuits, by a change in their relative position, the approach or withdrawal of core, tube, or secondary coil; the latter being by far the superior method. The object to be attained is the *gradual* variation of intensity, without jarring or irregularity, from a minimum to the maximum of electro-motor force.

The removal of the core or its complete covering by the tube, whilst rendering the current very weak, does not reduce it to a minimum, and would necessitate the addition of a rheostat for thorough control; in instruments in which the core serves as a magnet for the interrupter it cannot be moved, and the tube is a superfluous addition and a detriment, as it increases the distance between core and primary, or primary and secondary circuit, weakening the induction effect. Moreover, the galvanometric or measurable intensity of the current is not altered by removal of the tube, however much the physiological effect is varied. The quantity of flow remains the same, its curve only being changed; hence the tube is used only in pocket-instruments, which must be very compact, cramped into the smallest possible space, which does not admit of a moving to and fro of the large secondary coil.

The only simple and practical method of varying the current is by approach and removal of the outer or secondary coil from the inductors,—primary coil and core,—which are fixed, and thus the induction force can be varied from 0 to its maximum, and the change established with regularity and precision. In the great majority of instruments, and in every more exact apparatus, the gradation of induction force is produced by the sliding of the secondary coil over the primary, and only to those so constructed do I refer in speaking of faradic instruments, as the galvanometric, like the physiological effect, decreases with the removal of the secondory coil; and not alone is the effect varied, but it can be graded, by the extent of separation of the coils, as the electro-motor force induced in the secondary circuit is nearly proportionate to the distance between the centres of the coils. The increase is

very slow until the coils begin to overlap, then the current increases rapidly with the pushing in of the coil; at four centimetres from complete contact the ascent grows less brusque. The increase of electromotor force is less marked with still farther pushing in of the coil; when near the end, at one centimetre, the effect is suddenly much reduced and the increase is still less until contact is made.

Not alone is this the most satisfactory method of gradation, allowing a gradual and regular increase of current and admitting of its utilization throughout the entire range of its electro-motor force, but it admits of a certain definition of current-strength, of record and comparison, by a subdivision of the sledge or slide, at will, in inches or centimetres, so that the position of the secondary coil can be noted as an index of electric force.

The physiological efficiency of the current can also be graded from 0 to the maximum of physiological force by the contact-breaker in properly-constructed instruments, by varying the rapidity of interruption; but this, like the tube of Duchenne, in nowise affects the measurable intensity; although a regulator of therapeutic value, it is useless for purposes of dosage, since the same status of the interrupter has a different significance for different current-intensities as it has for nerve and muscle.

B. Batteries Used.

I will not here refer to the rotary or magneto-faradic instrument, as it is antiquated and rarely used, although perhaps preferable under certain circumstances, for its effect upon diseased muscle and for its convenience upon the frontier or in distant posts, as an instrument much less liable to disturbance, and not dependent for action upon solutions which may evaporate or deteriorate or are entirely out of reach; so also in emergeucy cases it is serviceable, as always ready for action.

Diseased muscle reacts more readily to the magneto-faradic than it does to the galvano-faradic current, as the rise and fall of potential in the former is less rapid, and time is an important element for the muscle current. Therapeutic tests have proven this, and Gaiffe describes a case of lead poisoning in which the muscle did not react to the galvano-faradic current, but was forced to response by the magneto-faradic.

Healthy nerve and muscle react to from 0.28 to 0.56 micro-coulomb of a condenser discharge (Edelmann), and time is a factor in the effect of the discharge on diseased muscle, healthy muscle reacting to a condenser discharge of $\frac{1}{10000}$ second, whilst diseased muscle needs from $\frac{1}{1000}$ to $\frac{5}{1000}$ second, and the greater length of time of the magneto-faradic discharge induces its more potent effect on diseased muscle. The galvano-faradic are the medical instruments of the present day, and these, as universally used up to this time, are constructed on one and the same plan, varying only in shape and size and in the mechanism and

perfection of their component parts. For the proper utilization of the variable and valuable therapeutic properties of the faradic current an apparatus more perfect in its interrupter and coils is necessary, but I shall here confine myself to the instruments now in general use, as these are the ones with which the physician must deal, for the present at least, until the new apparatus is more generally understood and introduced.

The faradic battery, or medical induction apparatus, is an electromotor in which we utilize the effect exercised by change of force in electrized or magnetized bodies upon neighboring circuits, and in which the closing current preponderates over the opening current, upon which physiological power is concentrated so as to give this the utmost efficiency; this opening current, or current of break, is the essential feature of the direct or extra, and likewise of the induced secondary faradic current, as well as the gauge of strength and direction of both.

I need not describe all trifling differences of construction, prominent among which is the Kidder single or continuous-coil apparatus, consisting of a series of three or four conaxial coils, movable over each other, in which the terminals of the secondary coils are not free as in the ordinary instrument, but connected with the primary circuit from which the current is taken, so that the primary as well as the induction flow is utilized. Since the individuality of the primary coil, an idea advanced by Duchenne and long retained, is proven a myth, and the peculiar effect ascribed to it has been shown to be due mainly to the quality of the coil,—the short, coarse wire,—we no longer use the primary current. We can obtain the same effect from a similar secondary coil, the alternation of the secondary current and the induction effect in no way interfering; so that we now ignore the primary circuit, which does not truly give a pure interrupted galvanic current, as the induction effect preponderates, but we arrange the apparatus so as to concentrate its efficiency upon the secondary circuit, thus obtaining uniformity and a much wider range of variation, greater precision, and the possibility of comparison.

Such is even the modern instrument, with variation in shape and size in accordance with the purpose for which it is constructed, and greater or less delicacy and perfection of mechanism according to price; but at best it is incomplete, and ere long I hope to be able to present to the profession an instrument which will enable us to properly utilize the valuable qualities of faradic electricity.[1]

In the instruments as now in general use we have three distinct styles: (*a*) the pocket-battery; (*b*) the portable or box battery; (*c*) the stationary or sledge instrument. In all the vibrator is acted by the coil current or primary battery flow, whilst in my new apparatus the inter-

[1] I may add that this instrument has just been completed, and has been displayed by the maker at the World's Fair, receiving the highest award; and I can safely say that we may soon hope to see it in the hands of the profession.

rupter is propelled by a separate motive power, so as to interfere in no way with the current proper.

(*a*) The type of the *pocket-battery* is the small Gaiffe instrument (Fig. 8), a neat box no larger than an octavo book, with two small sulphate-of-mercury cells, *L*, and with fixed coils, *M*, the core serving as attractor for the spring interrupter, *P*, the current-force being varied by the sliding tube, *R*. Extra and induced current, or both united, can be utilized from the connections in *E* by brass sponge-holders, *N*, or the metal electrodes, *T*. The battery-salt is carried in the bottle, *K*. Similar small instruments are made in the United States.

(*b*) The instrument most generally used is the *box-battery*. This is of moderate size and so arranged that it is portable, and yet can be made so complete that it answers all purposes and is in general use as an office instrument. These box-batteries vary greatly in size and perfection of construction, and are all equally serviceable for purposes of irritation or stimulation; yet the great majority of instruments do not admit of any other variation of current than in strength, as they have only the spring

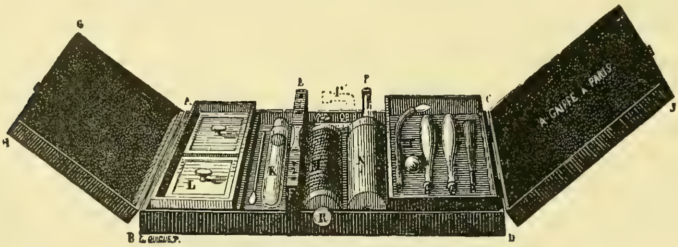


Fig. 8.—Pocket-Battery.

interrupter, which cannot be adjusted sufficiently to admit of a physiological variation of current, and they mostly have but one secondary coil, and that of no great length of wire, thus giving a sharp current. One of the most perfect of these instruments is the box-battery (Fig. 9) constructed in accordance with my earlier suggestions, and possessing controllable contact-breakers, which are well adapted for current-interruptions within moderate limits, and of greater variability than in other instruments. We see the three coils, one in use and two others stowed away in the receiver, and three contact-breakers; the rapidly-vibrating spring, adjustable by the screw-head, *D*; the slow interrupter, whose beats are varied by the screw, *C*, and the single impulse-key, *H*. The galvanic flow is established by inserting the zinc, *F*, into the adjoining bichromate-of-potash element, and making the battery connection by means of the metallic bridges, *E E*. The coils with which this battery is armed are those first advocated by me in 1886: Coil I, 577 winds, 0.8 ohm resistance; Coil II, 1750 winds, 13 ohms resistance; Coil III, 4000 winds, 250 ohms resistance. They accompany every instrument and suffice for ordinary needs, but for special or more delicate work others

must be added, as they are used with the new apparatus, and can be fitted to this. Innumerable very excellent box-batteries are made, but all on very much the same plan, with no possibility of current variation save by the sledge; though we must make an honorable exception of the Gaiffe and Flemming and the instruments of the Galvano-Faradic and Dry-Cell Battery Company, the latter of which have but quite recently appeared; in fact, our American instruments now far surpass those made in other countries.

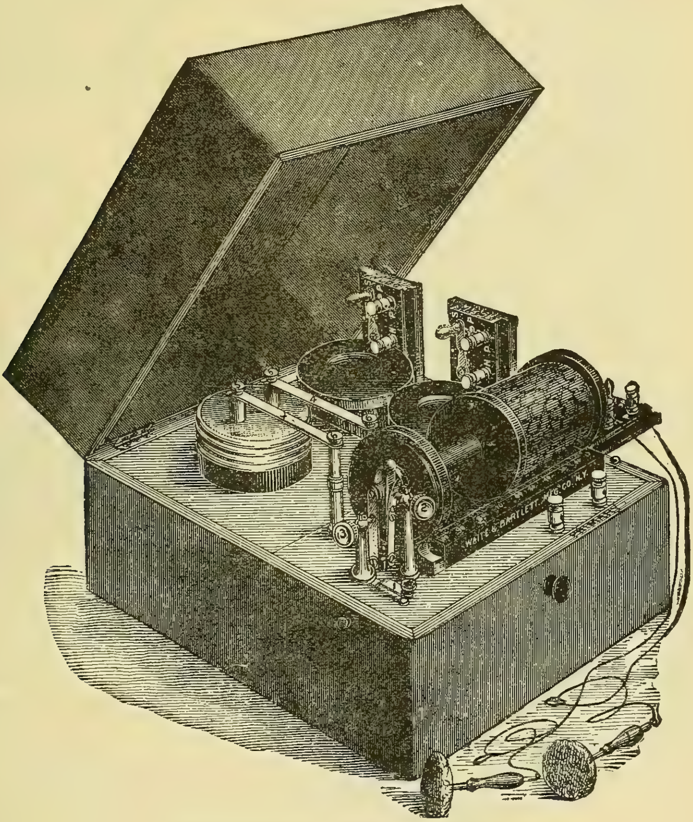


FIG. 9.—BOX OR PORTABLE BATTERY.

(*c*) *The Sledge Battery.*—The most perfect instruments, such as are furnished for cabinets and used by specialists, though on the same principle, are not boxed up, and are always made in the form of the Tripier or du Bois-Reymond sledge, a long slide or sledge admitting of an extended withdrawal of the secondary coil, thus yielding maximum effects and minimum currents for delicate physiological work. The utmost perfection of mechanism is found in this form of the faradic apparatus, for which the galvanic force is supplied by a Grenet

cell, or a battery of from 2 to 4 Leclanché elements. In most American instruments of this form the core is the magnet which serves the vibrator, whilst in those of foreign make the trembler is attracted by a small electro-magnet distinct from the core; though I know of but one, save my new apparatus, the Edelmann faradimeter, in which it is propelled by an independent force; yet such must be the case if any precision is to be obtained.

Fig. 10 is one of the best instruments of this kind, showing an ingenious contact-breaker, I, attracted by the small electro-magnet, E, which varies the interruptions from 1 to 50 per second by the change in the slant of the bar, I, in moving the foundation, L, from L' to L'', and by varying the position of the globular weight, S; P is the single impulse-key, and i the current-reverser.

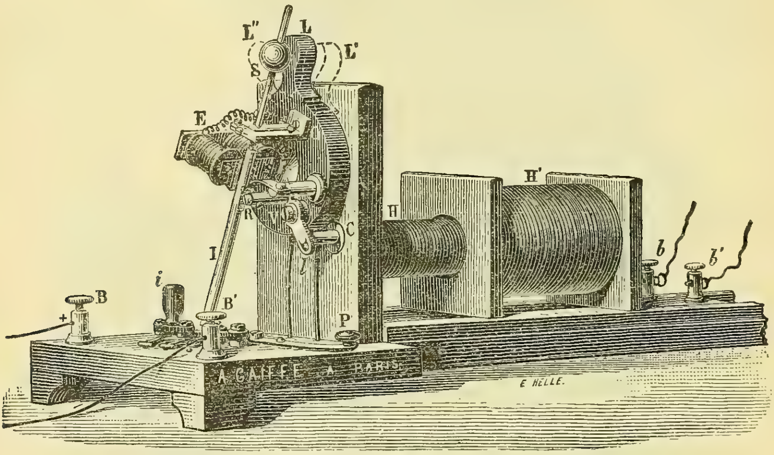


FIG. 10.—SLEDGE INSTRUMENT.

Fig. 11, varying only in detail from the box-battery, is the most complete of the old-style instruments made to supply a medical current as developed by the vibrator without the aid of the independent controllable contact-breaker. The cut represents the old instrument with the vibrator as propelled by the inducing current and attracted by the core, whilst the new apparatus, with the same vibrators and coils, is so arranged that the battery flow for each is independent of the other, and both vibrator and coil current is supplied with a rheostat so that every possible modification of force can be obtained, and the rapidity of vibration need in no way be influenced by the variations in the inducing flow, as is the case in all other instruments in which a change in the position of the coils or the force of the inducing flow at once alters the rate of vibration. This apparatus shows the same arrangements for contact-breaking as Fig. 9, but is supplied with some additional details, such as a fine movement, J, for the gradual sliding and pre-

cise adjustment of the coil on the sledge or scale. The long coil of fine wire is supplied with a lever, *K*, by means of which different lengths of wire can be utilized; thus, in one coil of 6000 feet the wire is so switched off that it may serve as a coil of 3000, of 4500, or of 6000 feet. Any number of the four elements supplying the primary force can be employed, by means of the lever *A*, from 1 to 4, as may be demanded by the nature of the circuits employed, the resistance of the battery and body circuits, or the effect to be obtained.

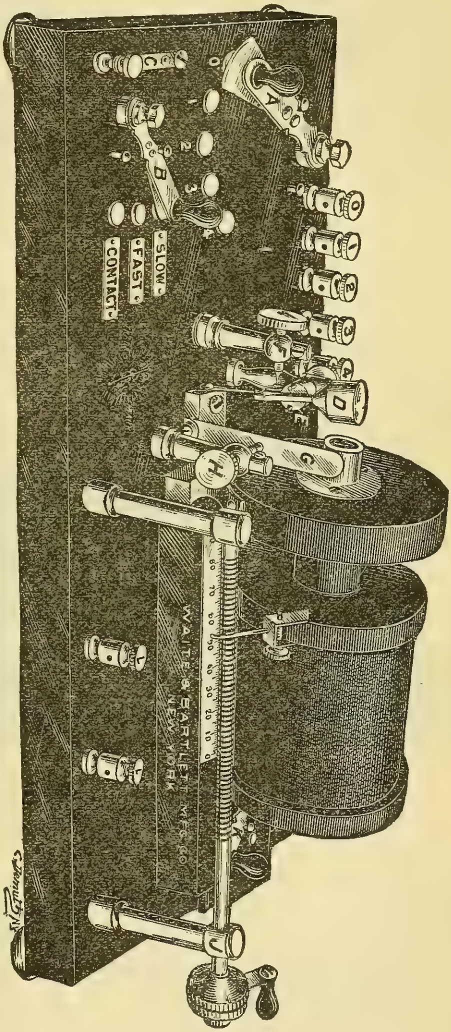


FIG. 11.—SLEDGE INSTRUMENT (ENGELMANN BATTERY).

1 to 4, binding-posts to connect cells; *A*, lever to introduce 1, 2, 3, or 4 cells; *B*, lever to introduce for varying interruption, to use slow, fast, or single impulse; *C*, single impulse-key; *D*, slow vibrator; *E*, controller for slow vibrator; *F*, regulator for slow vibrator; *G*, fine or fast vibrator; *H*, regulator for fast vibrator; *J*, fine movement for coil; *K*, lever for insertion of different lengths of coil; *L*, *L*, binding-posts for rheophores.

An instrument varying in several important elements from any previously constructed is my new apparatus (Fig. 12), which furnishes all the different qualities of faradic current with the greatest possible range of variation and under the most perfect control; so that I may say that it is an instrument which will establish faradism on a firm basis as a therapeutic agent, since it admits of a perfect control of the current and of a precising so necessary to dosage; but it will also greatly extend the range of its applicability, since increased range of coils and rates of vibration give currents of therapeutic power hitherto unknown.

This instrument differs from all others, in the main, in the following points: (1) the separation of the vibrator or interrupter current from the therapeutic or inducing flow; (2) in the variability, controllability, and rapidity of the interrupter; (3) in the range and precise definition of the secondary coils; (4) in the possibility of interrupting or alter-

nating primary or secondary current at will. The cut represents the apparatus but partially.

The inducing current here used is entirely independent of the current which produces the interruptions, be it by means of the new contact-breaker here represented or by the series of vibrators which is also attached to the apparatus as made for me; this inducing current can be varied (*a*) by the use of any number of elements as introduced by moving the switch to points 1, 2, 3, or 4; (*b*) by the sliding of the coil on the graded sledge; (*c*) by the rheostat directly in front of the coil. The second rheostat, by the side of the first, is for the purpose of regulating the vibrator current, for single-impulse key, slow and fast vibrator, as in Fig. 11, but not represented here.

1. *Coils.*—To the right is the coil, with sliding scale and fine movement. The coils used in connection with the apparatus are devised for

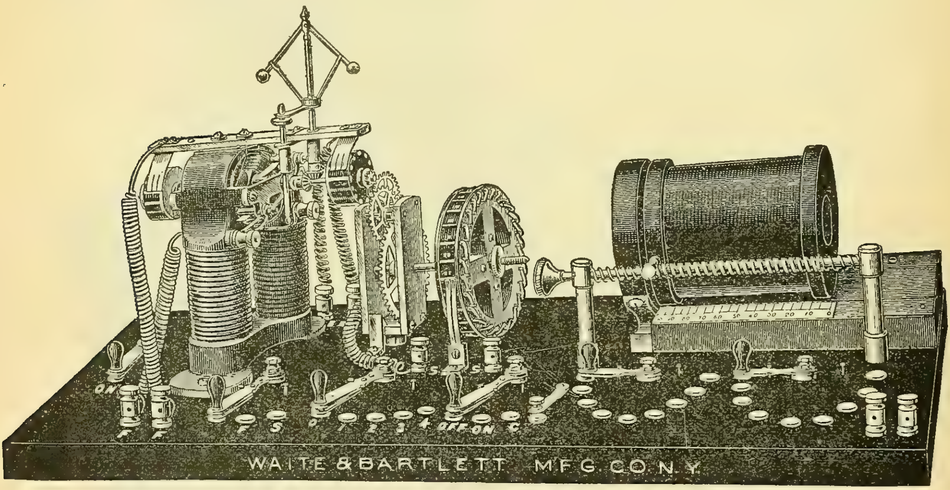


FIG. 12.[1]—NEW ENGELMANN BATTERY WITH VARIABLE AND CONTROLLABLE INTERRUPTER AND ALTERNATOR.

certain therapeutic purposes; their quality and quantity is designated by electro-motor force (number of winds) and resistance in ohms.

For motor, to the exclusion of sensory effect,—that is, the painless influencing of the muscle,—secondary coils of the lowest possible resistance are used, *i.e.*, coils with a comparatively great electro-motor force:—

[1] At the very last moment, while reviewing the proof of this paper, I was fortunate enough to receive this cut (Fig. 12) of my new faradic apparatus, to the perfecting of which my leisure moments during the past year have been devoted, and it is by reason of the tardy completion of this new apparatus, new in principle and in construction, that I can here give but a brief description of its salient features. I must add that the admirable carrying out of my ideas and the perfection of mechanical details are entirely due to Mr. Harry F. Waite, of the firm of Waite & Bartlett, New York.

Coil I: 528 winds, 0.8 ohm resistance.
Coil II: 6500 winds, 4.1 ohms resistance, No. 32 wire in multiple.

The opposite condition—revulsion, nerve irritation, without affecting the muscle—is produced by a coil of high resistance and low electromotor force:—

Coil III: 528 winds, 180 ohms resistance.

The utmost penetration, together with general therapeutic effects, is obtained by coils of greater electro-motor force and higher resistance:—

Coil V: tapped at three points, 4000, 6000, and 8000 winds, from 250 to 750 ohms resistance.

Coil VI, producing the utmost sedative and even anæsthetic effect, is a coil tapped at 5600, 9600, and 13,000 winds, with a resistance of 2500 ohms to its highest electro-motor force.

Coil IV (II of the old set) gives rather a sharp, yet penetrating current, 1750 winds, 13 ohms resistance.

To better illustrate these figures I will say that the most efficient of the coils in general use have been those of 3500 to 4000 winds, or 2000 feet. Each of the coils I have in this apparatus answers a definite purpose, attaining the desired result best without complication by other unnecessary and often deleterious effects.

2. *Contact-breaker.*—To the left is the contact-breaker or alternator and interrupter, a small motor propelled by an accumulator or by a Grenet cell, on its shaft an interrupter to one side and an alternator to the other. This contact-breaker serves to interrupt the current from 2500 to 50,000 times a minute: slower interruptions are produced by the large wheel in the centre of the figure, which also serves to determine the rapidity of interruption.

The advantages of this interrupter are (1) that it is propelled by an independent force, and may be used as interrupter or alternator for secondary or primary current or for the galvanic; (2) that the rate of interruption is perfectly controllable and regular, in no way influenced by the intensity of the therapeutic or inducing current.

The perfect controllability of this instrument, by speed indicator, rheostat, and am-meter, enables us to record and dose the faradic current, and its rapidity enables us to secure sedative and anæsthetic effects which can be obtained in no other way.

The absolute precision of record is perhaps the most important feature, as this is something which has been repeatedly attempted but never hitherto obtained, any comparison with the tuning-fork being at best but vague and only possible now and then for an experiment, but of no practical value for the office or for clinical work, and, moreover, a regulation of vibrators within the wider range necessary for therapeutic purposes is impossible, at least for actual work. Higher rates of interruption can easily be obtained, but my experiments have shown that this is practically useless for induction apparatus as now constructed; and

until electro-motor force and resistance of primary and secondary coils, as well as the quantity of the primary flow, is greatly changed, we cannot utilize interrupters more rapid than this, giving 50,000 interruptions per minute.

C. Electrodes.

Electrodes, or instruments for the therapeutic application of the induced current, are many and varied in shape and material, according

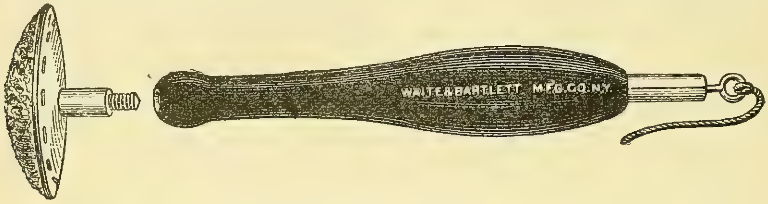


Fig. 13.—Sponge-Covered Disc.

to the part to which they are to be applied and the purpose for which they are to be used; yet the paucity and simplicity of the electrodes which accompany the average faradic apparatus, the old-time brass or vulcanite sponge-cup, or the now universal sponge-covered disc, has done much to limit the use of faradism, these being given into the hands of the physician as *the* instruments for its application, yet serviceable only for a very limited range of therapeutic use.

Strange as it may seem, the electrodes, or instruments devised for the therapeutic application of faradic electricity, are more numerous and

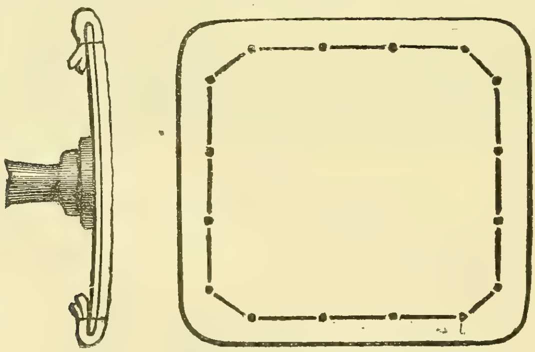


Fig. 14.—Plate Electrode.

diversified than those for the galvanic current, as its uses are more varied and it is more liable to be applied to deep-seated organs and to the cavities necessitating instruments of peculiar construction for each separate part; numerous electrodes are made for localized and bipolar faradization, for faradic massage and the faradic bath, and I will briefly describe the more important, as they are by no means so well known as galvanic electrodes.

I. ELECTRODES FOR GENERAL AND LOCALIZED FARADIZATION.

In polar treatment we use the dry metallic electrode for superficial, revulsive, or skin effects, and the moist electrode for muscles, nerves, and deep-seated tissues, for the penetrating current. Metallic electrodes are the circular or rectangular discs and plates of the instruments in Figs. 13 and 14, small globes and cones, and the faradic brush,—a bunch of fine wires trimmed so as to present a smooth, even surface. Instruments of suitable shape are made for the application of this current to the vocal cords, the uterus (Figs. 15 and 16), and the bladder.

In scientific experiments it must be remembered that the polarization of these electrodes affects the current more or less, and that for purposes of precision non-polarizable electrodes must be used, or at least

FIG. 15.—CUP-SHAPED ELECTRODE FOR OS UTERI.

the extent of this action must be studied and accounted for. Every particle of oxide on the surface of the electrode offers a resistanee to the current, and thus weakens its effect; so that much current-strength is lost in old, badly-kept instruments. More generally used are the moist electrodes, made by covering the conductor with an adaptable moisture-retaining substance, for penetrating, nerve and muscle currents.

The sponge was, until of late, universally employed,—an uncleanly appliance, as it was used again and again, for patient after patient; not alone dirty, it was imperfect, as its coarse meshes did not admit of close adaptation to the part to which it was to be applied; and as resistance and density of current are in direct relation to the surface of the electrode, this is an important factor; unless perfect coaptation and contact at every point exist, the size of the electrode is by no means equivalent

FIG. 16.—BEARD AND ROCKWELL'S INTRA-UTERINE ELECTRODE.

to its active surface, that surface being constituted by the points in close contact with the tissues. Moreover, the penetrating power of the electric fluid is dependent upon the resistance offered; and as, for induction currents especially, the surface or skin resistance is great, the perfect coaptation of the electrode is of importance, as it serves to overcome this, lessens the pain, and adds to the efficiency of the current by causing a diminution of the resistance of contact or passage (Uebergangs Widerstände). Cloth and the ordinary chamois, even when wet, has a rough surface and does not admit of perfect contact as an electrode covering; nor does it hold enough moisture, upon the superabundance of which we must rely for perfect contact, as no material can adapt itself to every little

irregularity of the skin as water does. The saturating fluid serves to make more points of contact, and, by moistening the dry epidermis, to reduce its resistance,—an effect which is increased by increasing the conducting powers of the fluid by warmth and the addition of a small percentage of salt.

We need, for penetrating, painless currents, electrodes with the greatest possible number of points of contact for their surface, as the

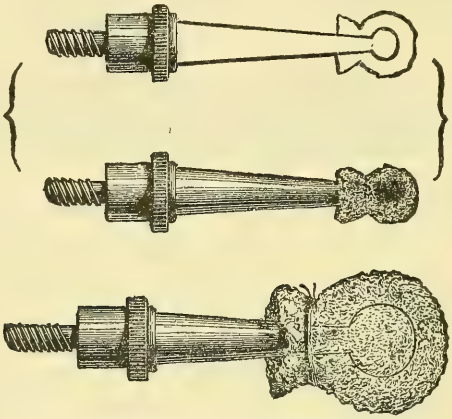


FIG. 17.—BALL ELECTRODE.

density in each is diminished by an increase in their number; hence the metallic conductor of the electrode must be covered by a pliable and adaptable material which will absorb and hold an abundance of fluid. The cleanest and most simple is absorbent cotton, which is renewed for each application: this can be used on all smaller electrodes, being renewed for each application. Punk, which I use to cover larger plates, is of finer texture and an equally good absorbent, and can be used to advantage on the smaller instruments, a supply being kept on hand

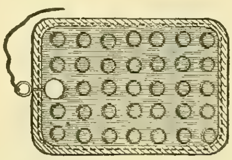


FIG. 18.—ENGELMANN'S PUNK ELECTRODE.

for renewal. Metal or carbon plate, ball or cone (Figs. 13, 14, and 17) are surrounded by a thick layer of the cotton, which clings when moistened and needs no fastening to hold it in place; a rubber band will serve to hold the punk. For the larger plate electrodes (Fig. 14) this can also be used, and if it is to be permanent it may be held in place by a fine, thin chamois; one or two layers of well-selected punk, in place of the cotton, underneath the chamois, are most satisfactory and make an admirable

conductor. The basis is a thin sheet of pliable tin, lead, or amalgam, perforated in a number of places to give free access to the fluid.

This is the same electrode (Fig. 18) as the one I recommend for the indifferent pole in galvanization, and made in the same sizes, the smaller

FIG. 19.—KING'S RECTAL ELECTRODE.

numbers being more generally serviceable for faradization; being flat and pliable, it is extremely convenient for abdominal application, as it can be slipped under the dress without disturbing the patient, a warm towel

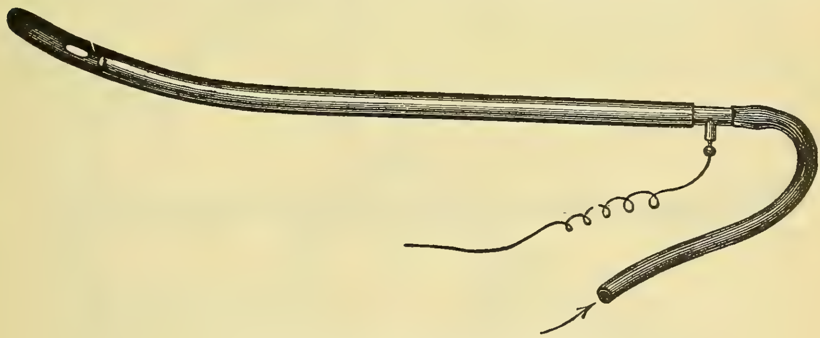


FIG. 20.—BOUDET'S RECTAL ELECTRODE.

or a piece of rubber tissue serving to protect the garment from contact with the moist plate. For labile applications the Erb electrode (Fig. 14) with handle must be used, but covered in the same manner, the smaller

FIG. 21.—TRIPIER'S RECTAL ELECTRODE.

sizes always with absorbent cotton or punk, and these, especially when long and narrow, one-half by two inches, two by four, two and one-half by five, though not so generally made, are very useful in local faradization.

Character and size of the electrode are prominent factors in deter-

mining therapeutic effect, as upon this depend density and resistance, the character and effect of the current, and these points must always be noted for purposes of record and comparison, In body-cavities a quantity of fluid to which the current is carried by the electrode may serve as distributor; thus, in the rectal electrode of King (Fig. 19) or that of Boudet (Fig. 20) warm salt water is used as the active pole within the bowel in the treatment of constipation. This is a great improvement over the old-time instrument with metallic end, which so long stood in the way of this valuable method of treatment, which, if ever attempted, was soon discontinued on account of the sharp, painful current from the metallic electrode. which, moreover, was far less penetrating, less diffuse

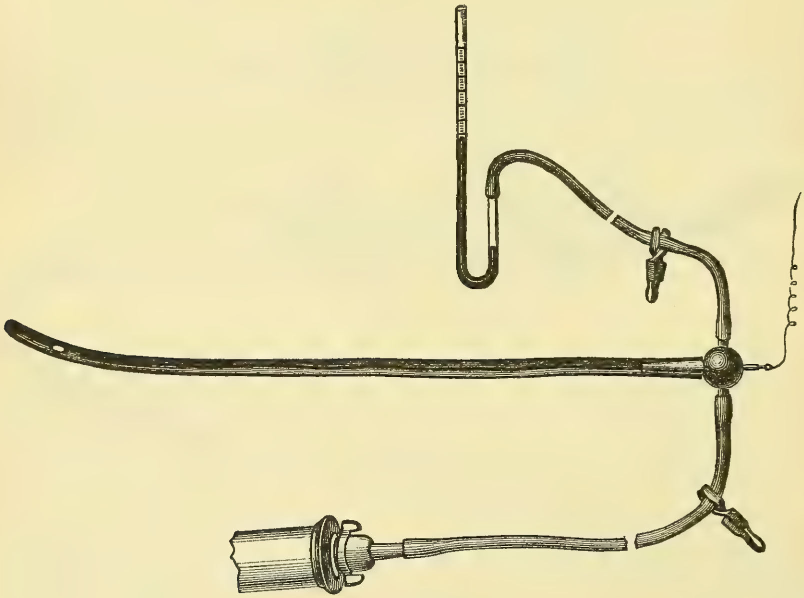


FIG. 22.—VESICAL ELECTRODE OF BOUDET, WITH MANOMETER.

and effective as a muscular stimulant and contractor. In this instrument, as in that of Boudet or the new electrode of Waite & Bartlett, no metal can possibly come in contact with the tissues; in the former the vulcanite bulb, in the latter the rubber catheter, through which the fluid is injected, guards the tissues against the inclosed metallic conductor.

A similar instrument is the vesical electrode of Boudet (Fig. 22), to which a manometer is attached for the purpose of recording the various phases of the disease, by measuring the contraction of the vesical muscle produced by the current in the course of the treatment.

(*b*) *Bipolar electrodes* are those in which both currents are applied by means of one and the same instrument, which carries the two poles, and are mostly used upon the mucous membranes, within body-cavities, in

uterus, vagina, bladder, and rectum. Thus the rectal electrode of Tripier (Fig. 23) and a similar instrument by Bergognié (Fig. 24), supplied with a manometer for the study of the contractile powers of the sphincter muscles. The rubber bulb, *B*, is compressed by the contraction of the muscle as it responds to the electric current, and the extent of this reaction is indicated by the manometer connected with the bulb by a rubber

FIG. 23.—TRIPIER'S RECTAL ELECTRODE.

tube, *C*. The instrument is a valuable one for the determination of the cause of constipation, the determination of the extent of muscular weakness, and the observation of its improvement under this admirable, but little-used, method of treatment. Whilst this instrument is admirably adapted for purposes of observation and measurement, it is, like all metallic electrodes within the bowel, unfit for continued treatment.

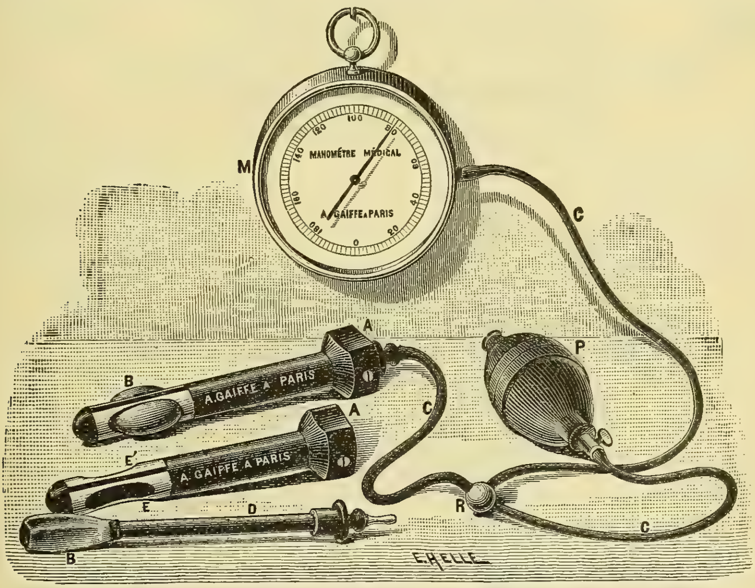


FIG. 24.—BIPOLAR RECTAL ELECTRODE OF DR. BERGOGNIÉ, WITH MANOMETER.

Only the cotton-covered instrument, or, better still, the catheter apparatus, with water as the conducting agent, should be used, and, further, it is rarely the case that only one point is affected, demanding the localized application by a bipolar electrode; the polar method, with one abdominal electrode, is decidedly preferable. Bipolar intra-uterine applica-

tions are far more frequent and numerous: instruments are made for this purpose, but these are mostly useless or dangerous in all but large cavities, as they are not pliable, and of necessity not sufficiently slender, car-

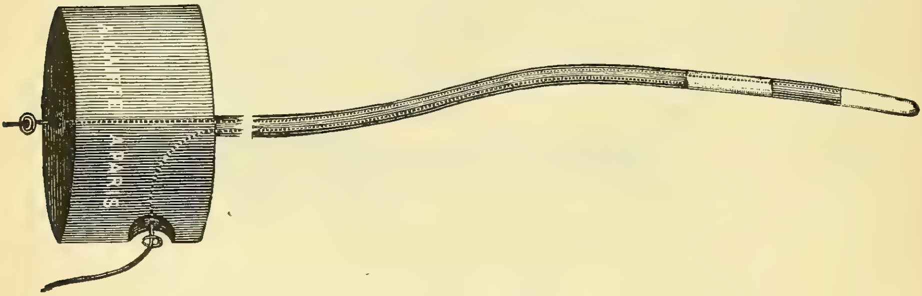


FIG. 25.—BIPOLAR INTRA-UTERINE ELECTRODE OF APOSTOLI.

rying two insulated conductors; so that they cannot be inserted in a narrow or curved canal unless some force is used. Fig. 25 is the bipolar intra-uterine electrode of Apostoli, and Fig. 26 that of Gunning. Va-

FIG. 26.—GUNNING'S FLEXIBLE DOUBLE-CURRENT INTRA-UTERINE ELECTRODE.

ginal electrodes of various kinds are made; that of Tripier consists of the insulated blades of a speculum, but mostly the two poles are upon a rubber bar, as metallic circlets (Fig. 27), one to two inches apart, or

FIG. 27.—BIPOLAR VAGINAL ELECTRODE OF APOSTOLI.

longitudinal strips parallel to each other: the surface of the metal is generally even with that of the non-conducting stem and does not come thoroughly in contact with the tissues; this difficulty is obviated in the

FIG. 28.—BIPOLAR VAGINAL ELECTRODE.

admirable instrument (Fig. 28) recently furnished by Waite & Bartlett, in which the metallic poles are rounded, protrude over the stem, and are so arranged that they can be approximated to or removed from each other.

Quite a variety of electrodes are constructed for diagnostic purposes, especially for the testing of cutaneous sensibility: these are pointed, conical instruments, and carefully-made wire brushes; but as the points of the wires in these brushes cannot all be made perfectly even, bundles of wires imbedded in a vulcanite mass are used; the ends, cut square and polished, present a smooth, metallic surface, in which each terminal is in the same contact, and it is sufficiently large (two centimetres in diameter), with a sufficient number of points to overcome any source of error from perspiration, irregularities of the skin, small nerves or glands.

II. MASSAGE ELECTRODES.

For the application of *faradic massage* we use rollers or plates made of a conducting material, and supplied with a handle, so that the

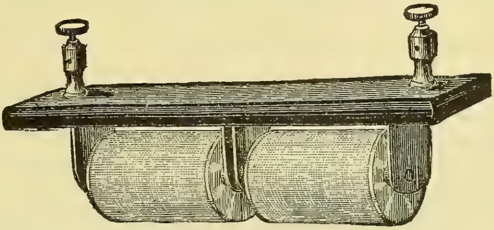


FIG. 29.—PIFFARD'S ROLLING RHEOPHORE.

current is carried by the same instrument which exercises the pressure upon the tissues. The electrode of Mordhurst is a plate, varying in size according to the part of the body to be treated, with a medium of one hundred and twenty square centimetres; of the rollers, the rheo-

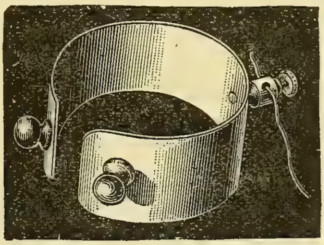


FIG. 30.—WRISTLET ELECTRODE.

phore of Piffard (Fig. 29) is a type; another instrument is the wristlet electrode (Fig. 30) for rubbing, massage, and digital diagnosis.

III. BATH ELECTRODES.

The electrodes in use in the *faradic bath* are generally large plates, preserved from contact with the body by non-conducting, protruding frames (sometimes an air-cushion is used), the metal plate being some ten by twelve inches for the back or neck, and nine by eleven at the

foot end. Smaller electrodes are made for the purpose of localizing the current in the bath to some one part of the body; but for a general distribution of the bath-current the large plates generally used are entirely unnecessary, as a few inches of the terminal of the battery-wire flattened out or coiled answers precisely the same purpose, and must, of course, be likewise preserved from contact with the body.

Local baths or douches are applied by means of metallic spouts, with a non-conducting handle; these spouts, like those of a shower-bath or watering-pot, are perforated; the water is forced in delicate jets through the numerous small openings, the spray being the rheophore by which the current is applied to the part. For back and chest the spouts are rectangular, or round, some two inches in diameter; a long, narrow one is made for the spine, three-fourths to one inch by two or two and one-half inches; a plate-electrode is, of course, necessary for the indifferent pole.

IV. CHOICE OF BATTERY AND ELECTRODES.

The proper selection of apparatus, of battery and electrodes, is all important to the physician who would use faradism to advantage in his practice, and afford his patient all the benefits of this variable and effective form of electricity. Notwithstanding the off-hand statement made in so august a body as the International Congress of Electricians, only one year ago, that "der kleine Spanner," the average small German box-battery, was sufficient for all purposes, the *choice of an instrument* is of *great* importance, and, although a recent text-book tells us that it is "of small importance," as "the details of construction can safely be left to the maker," and certainly far less important than the choice of a galvanic apparatus, this is by no means the case. The choice of the faradic apparatus is all-important, as upon its *mechanism and construction* depend the *character* and *efficiency* of the current, whilst this is not the case in the galvanic battery. The galvanic current is the same whether taken from a home-made instrument of two dozen fruit-jars into which the carbons and zincs are placed, if they are but properly coupled, or if it is from a battery in mahogany box or cabinet; but the character of the faradic current varies more or less with every detail of construction, with length, thickness, and kind of core, dimensions of coils, length and thickness of wire, insulation, number and character of interruptions; and its utility depends greatly upon the method of contact-breaking and of gradation of current.

The physician who desires not only an irritating, stimulating current, but wishes to obtain the utmost efficiency and variability of faradic electricity, must consider various points. Granting precision and perfection of construction, as we may expect this in instruments from any reliable maker, the essentials to be looked for are as follow:—

1. The possibility of varying the number of interruptions *at will*,

from one up to *at least fifty thousand per minute* (50 per second—3000 per minute—is the limit for the majority of instruments now used).

2. The separation of the inducing flow, or the coil current, from the battery power which acts the trembler; in other words, a separate motive power must be used for coil and contact-breaker in instruments of precision from which an even and thoroughly controllable current is to be expected.

3. The gradation of current-strength by the sliding of the secondary coil over the primary upon a scale-sledge, which for a perfect instrument should indicate in micro-coulombs the current-value for each coil, for a given current, and for a given medium body-resistance, although until a more perfect method of measurement is discovered the simple division of the scale may answer. The mobility of the core is necessary, and, of course, on a scaled slide; but this is not for the varying of current-strength, but of current-quality.

4. The instrument must have a series of, at the very least, three secondary coils for muscle, nerve, and general effects; one with low resistance and as high an electro-motor force as possible, usually a short coil of heavy wire; another long, of not less than 5000 to 9000 winds, of very fine wire, with one intermediary.

This is the very least that can be asked; more must be demanded of an instrument from which the utmost efficiency and variability of current is expected. The series of coils must have a greater range, and each must be adapted to the special purposes for which it is constructed: for muscular stimulation, for counter-irritation, for sedation, and for general nerve and muscular effects. A fine-wire, multiple muscle-coil is desirable, a short fine-wire coil for counter-irritation, and also a sedative coil with from 1000 to 13,000 winds. Above all, the contact-breaker must be independent of the inducing current and be so arranged as to break the contact any given number of times up to twenty or fifty thousand per minute. As for the electrodes, I can only say that absorbent cotton or punk should always take the place of the old-time sponge; and perfect coaptation should be aimed at, whatever the nature of the application, unless revulsive. For penetrating currents the material in direct contact with the skin must be of fine texture, a perfect fluid-absorber, and in sufficient quantity to retain it in abundance: the carbon discs now in vogue are not as satisfactory as the metal, since they must be covered in the same manner to secure penetrating currents; the chamois or flannel covering with which they are sent out, as an accompaniment to the battery, makes an imperfect appliance, which but partially answers the purpose for which it is intended, the resistance being great and the adaptable surface comparatively small.

As electrodes must be selected with reference to the uses to which the current is to be applied, and the range of application is so extensive, the merits of individual instruments cannot here be discussed.

A great variety of efficient electrodes is to be had, each serving its especial purpose, and the practitioner will soon discover the long-ignored merits of the interrupted current if he will but study the nature of this pliable form of electricity and avail himself of its variable powers by using currents from properly-constructed apparatus, and apply them by rheophores adapted to the object in view. Let the demand be created, and numerous serviceable instruments will soon be placed within reach of all.

GALVANISM.

By J. MOUNT BLEYER, M.D.,
NEW YORK.

In preparing this *résumé* of research and investigation, so far-reaching and comprehensive, I naturally cannot fail to accord due credit to the tireless workers to whom our profession is indebted for its knowledge of electrical energy as we now understand it. Particularly let me thank those gentlemen whose works I have made use of, and to whom credit is given in the "Bibliography."

In touching upon the critical value of batteries and precision instruments employed by medical men, I shall leave what comment there is to be made to my co-editors and colleagues who have prepared the other chapters of this work, and upon whose ground I do not mean to tread. While engaged in my labors I kept in mind that all-important consideration, that most busy medical men will hail with delight and read with interest what little I have to say upon the elementary physics of electricity. This, it seemed to me, was all important for a clear understanding of the practical application and usefulness of electricity to the practitioner. The mathematical consideration of the science I have only superficially touched upon, but refer you to the many exhaustive treatises on electrical measurements for additional light.

Historical Sketch of the Rise of Electricity.

To wield the thunder-bolt was the marked attribute of the chief gods of old; the lightning-flash was the surest proof of the presence of the divinity. Indra, the Jupiter of the Hindoos, was the god of thunder; the Etruscan Tinia always guided the electric storm; Jupiter Tonans waved his thunder-bolt over trembling Rome; and in every form of ancient superstition a belief in the divine origin of the most startling of the heavenly appearances lay at the base of the national faith. When it thundered the grave Romans dissolved their political meetings and the wise Greeks listened with unfeigned awe. The gods spoke from the heavens in the rattle of the passing storm, or wrote their rage upon the earth in the ruin of the lightning-stroke. And now, like Indra, Tinia, or Jupiter, the genius of modern civilization bears in its right arm the thunder-bolt as its crowning attribute. It has snatched the lightning from the skies and made it the most docile of servants. The electric flash is busy day and night in doing the work marked out for it by our modern magicians. It flies swifter than Ariel to carry its master's message, and puts a girdle round the earth. It dives in mid-ocean, rides over desert and forest. It prints our books, prepares our

paper; it dissolves our gems and consumes platinum. An electric light turns night into day; electric processes aid almost every kind of mechanical labor; and the thunder-bolt of Jupiter is everywhere toiling in the cause of human progress.

Of all the achievements of modern civilization this is the most

FIG. 1.—BENJAMIN FRANKLIN.

remarkable. Steam is gross and material; there is little that is poetic or great in the rattle of the train or the roar of a monstrous engine. We can easily account for the mightiest of machines impelled by boiling water. Gunpowder and nitro-glycerin, oxygen and hydrogen seem the natural servants of inventive man. But when we attempt to catch the idea of the electric spark, it still appears almost as superhuman and ter-

rible as when it flashed fear into the hearts of Greeks and Romans. It obeys with scrupulous accuracy; it performs the smallest, as well as the most important, tasks with equal care; it is as docile as was the genie to Solomon's seal; and yet it still remains shadowy, mysterious, and impalpable. It still lives in the skies, and seems to connect the material and the spiritual. Whence come these tongues of fire; these sharp shocks; these pale, ghostly lights that play around us and mock the master they obey? Who is it that wields this electric element, which seems to be the very base and source of our existence?

Some such sentiment of mysterious awe pressed upon the mind of Thales, the Franklin of Miletus, when, twenty-five centuries ago, he probably discovered electricity.[1] A sage of Greece, the philosopher's keen eye watched the minute phenomena of nature. His mind was eager for every kind of knowledge. He studied morals, metaphysics, life; and upon a narrow field of facts he erected vast fabrics of speculation, which were designed to embrace the whole origin and destiny of man. Phœnician voyagers, who were in the habit, in that dim age, of sailing out of the Straits of Hercules, and, perhaps, of coasting along the desolate shores of Europe until they reached the Baltic, brought back from the savage seas of Prussia a substance greatly prized by the ancients for its fair color and delicate transparency. It was amber, or electron.[2] The natives found it floating upon the waves, or, perhaps, gathered it from the mines which still form a source of the wealth of Prussia, and the amber imported from the distant north was an important article of commerce with the southern natives. But to Thales it possessed a mysterious value. He discovered that electron, when rubbed, had the property of attracting to itself various light articles, as if endowed with volition. His discovery was the first step in the great science of electricity. But the philosopher did no more than record his observation and attempt to account for it, as he had already done with the magnet, by ascribing to amber a soul. He supposed that some hidden principle of life lay in the yellow jewel from the northern seas.

The discovery was never forgotten, and the peculiar property of amber was noticed and commented upon by various ancient philosophers. Theophrastus, three centuries later than Thales, observed the attractive power of electron, and perhaps lectured his two thousand disciples upon the animated gem. Pliny, the elder, also described the phenomenon, and believed, apparently, that the amber was rubbed into life by the action of his fingers. But the germ of the great science lay hidden in mystery. No ancient philosopher could for a moment have supposed that there was any connection between the animated electron and the wild electricity of the thunder-storm; that the same power was active

[1] Becquerel, Traité de l'Électricité; Pliny, N. H., i, pp. 37, 329.

[2] Ges Carthager, Bötticher, p. 75, thinks the Phœnicians reached Prussia. See Pliny, H. N., iv, p. 27; xxxvii, pp. 11, 12.

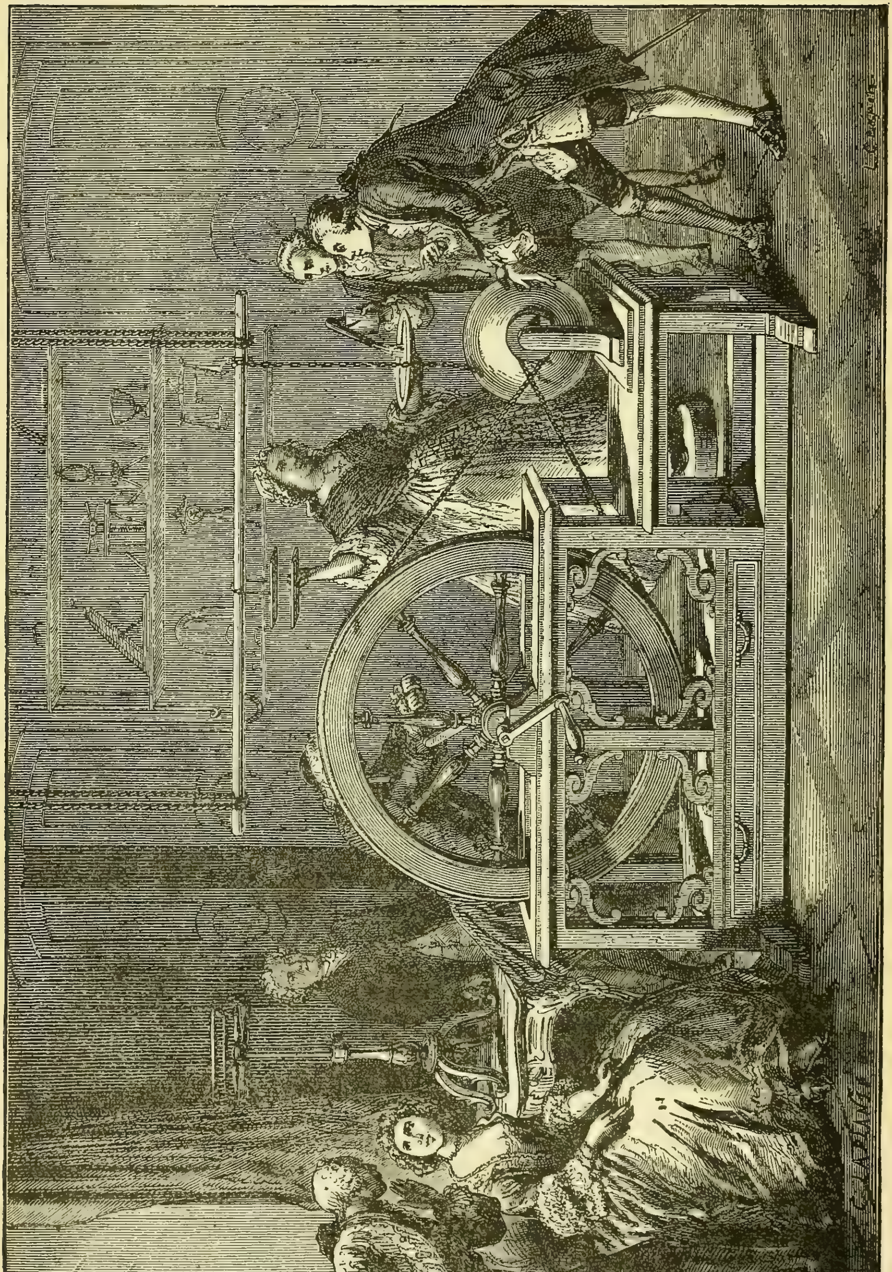


Fig. 2.—Hawkesbee's Electrical Machine.

in both, and that the secret of the amber was that of the thunder-bolt of Jove; that the precious electron was to create and to give a name to the most wonderful of modern discoveries.

Yet electricity, in all its varied phenomena, never suffered the puzzled ancients to rest.[1] It flashed along the spears of their long array of soldiers and tipped every helmet with a plume of flame. It filled even the immovable Cæsar with a strange alarm. It leaped down from the clouds and splintered the temples and statues of Rome, and did not spare the effigy of the Thunderer himself. It was seen playing around the ramparts of fortified towns, crowning their sentinels with a strange effulgence. Often the Roman or Greek sailors, far from land on the stormy Mediterranean, saw pale, spectral lights dancing along the ropes of their vessels or clinging in fitful outlines to the masts, and called them Cæsar and Pollux. But the science of electricity was still unborn. Meantime in ancient Etruria, the parent-land of Italian superstition, countless students were being instructed in the art of reading the will of the gods by the lightning.[2] The heavens were divided into various compartments. If the lightning-flash appeared in one, it was a favorable omen; if in another, it was fatal. The accomplished augurs, instructed by long years of study and toil, stood upon lofty towers, watching for the sudden gleam or a sudden peal of thunder, and knew at once by their divine art what undertakings would be successful, and when their warriors clad in brass should go forth to battle against Rome. The religion of ancient Etruria was almost a worship of electricity, and the land of Galvani and Volta was famous in the dawn of its history for the close study of electricital phenomena.

But no Tuscan augur or Roman priest made any progress in creating the science. Centuries passed away. Europe was torn by civil convulsions: men sank into barbarism and rose again into new activity; but the famous observation of Thales was never lost; and at length, in the opening of the seventeenth century, an Englishman named Gilbert began to study the properties of the electron. He was rewarded by a series of discoveries that, in the dawn of science, made his name famous over Europe.[3] Yet they were so meagre as to advance little beyond the early observations of Pliny. He enumerated various substances capable of producing electrical action; he noticed the influence of the weather on the electron and the magnet; and from his labors sprang up a science known as electricity. Gilbert's work, "De Magnete," was published in 1600, and soon the new science began to terrify and astonish men. Every fact as it was unfolded seemed spiritual and supernatural. Flames of fire played around the electrical substances in the dark; sparks glittered; sharp sensations, produced by the unknown

[1] Becquerel, i, p. 32. Plutarch, "Lysander," notices the luminous wonders.
[2] Müller, Etrusker, iii, pp. 1, 2. Arnob, vii, p. 26. Genetrix et mater superstitionis Etruria.
[3] Becquerel, i, p. 35.

agent, were felt by astonished operators; and a mysterious awe surrounded the birth of the wonderful principle. Men were almost inclined, like Thales, to invest the electrical substance with a soul.

An Englishman discovered electricity; a Prussian, in the land of amber, invented the first electrical machine. Otto Guericke, of Magdenburg, who also invented the air-pump, formed the instrument by which electricity could be most readily produced; he placed a globe of sulphur on an axle, to be turned by the hand of the operator, while with

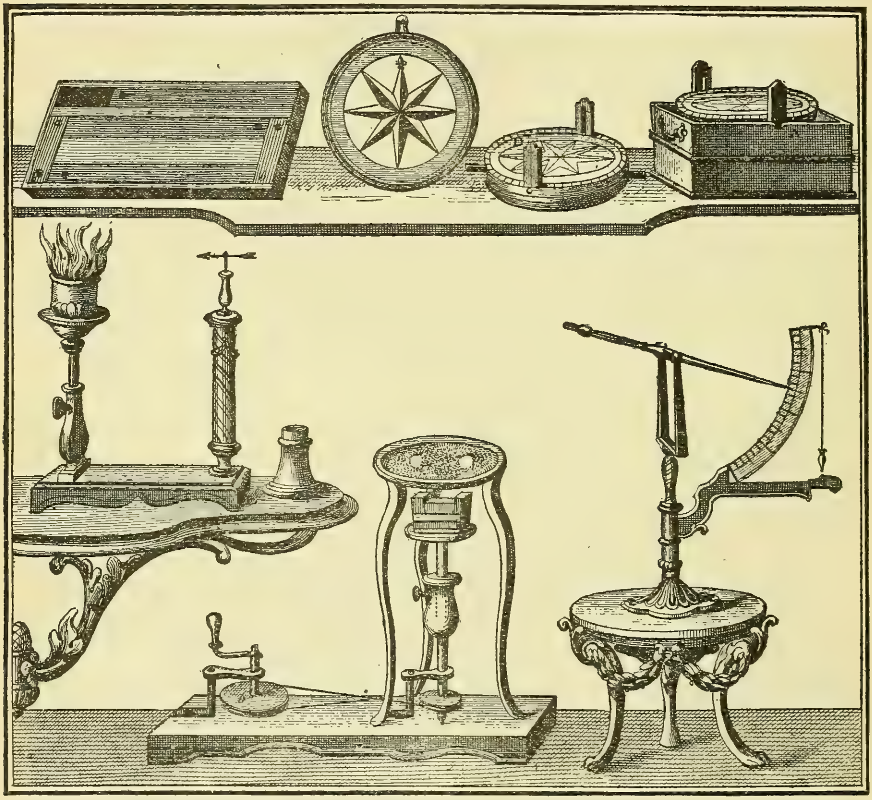


FIG. 3.—ELECTRICITY 150 YEARS AGO.

the other he applied a cloth to the sulphur to produce the necessary friction. It was a rude, imperfect machine, but it was at once found to have made a great revelation in the science. Electricity, which had heretofore been known only in its feebler forms, was now given out in sharp sparks, and displayed a thousand curious properties. Sometimes it attracted objects, at others repelled them. It seemed at times to exercise a kind of volition. The weather affected it sensibly; dampness dissolved its strength; it was capable, too, of influencing bodies at a considerable distance, and was apparently independent of the usual laws of

space. Yet the seventeenth century glided away, with its fierce religious wars and its wonderful voyages and settlements, while little progress was made in the knowledge of electricity. Newton paid no particular attention to the new science. He suggested, however, that the electrical substance was a subtle ether, filling nature, which could be set in motion by friction. Yet his bold, inquisitive mind was never attracted by the mysterious study; the flashes and sparks of the electrical machines seemed, perhaps, a puerile entertainment to the great student of nature's laws. Nor did any other eminent philosopher of the age suspect that

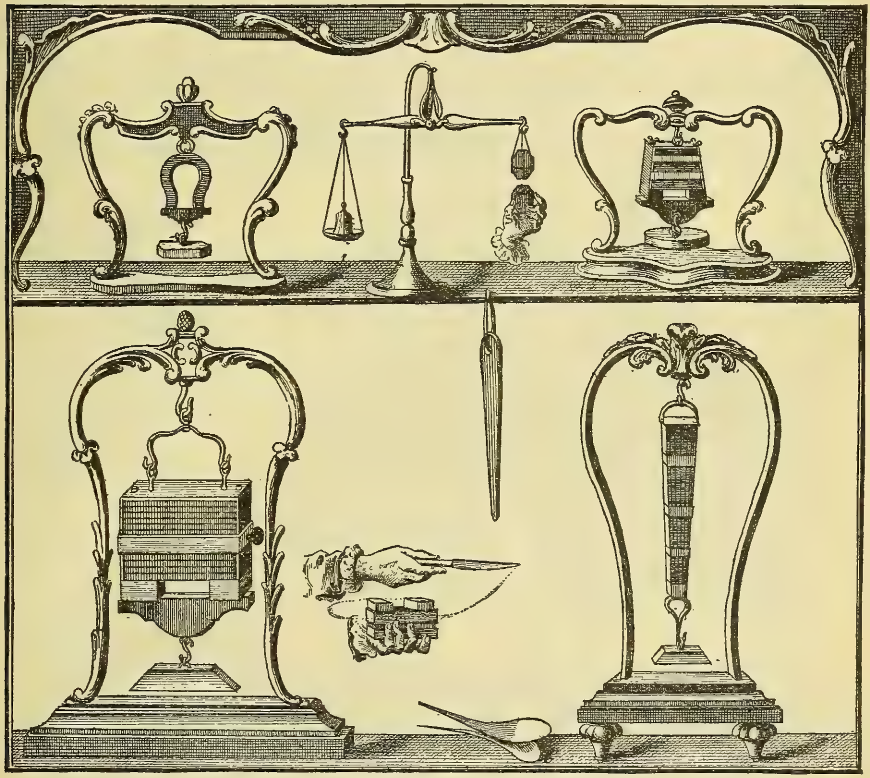


FIG. 4.—ELECTRICITY 150 YEARS AGO.

human hands would ever wield the thunder-bolt or unfold, by the aid of a globe of sulphur, the mightiest principle of nature.

But in the next century electricity sprang at once into startling importance. A series of wonderful discoveries aroused the attention of almost every scientific mind in Europe. England again led the way in the path of investigation. Hawkesbee invented the glass electrical machine,—a great improvement upon that of Guericke; and in 1730 Steven Grey began a course of experiments that unfolded the leading principles of the science.

France took up the study, and the curious discoveries of Dufaye and Nollet excited the wonder of their contemporaries. Dufaye transmitted the electric spark through a cord thirteen hundred feet long; and at length, in conjunction with the Abbé Nollet, he performed an experi-

FIG. 5.—L'ABBÉ NOLLET WATCHING THE EXPECTED DEADLY EFFECT OF A CONTINUAL ELECTRIC CHARGE ON ANIMALS.

ment, with wonder and terror, that seemed the crowning mystery of the science. Dufaye suspended himself by a silken cord, and was then filled with electricity by the abbé. He presented his hand to his companion, half doubting the truth of his own speculations, when a brilliant spark shot from one philosopher to the other, and filled both with an

equal surprise. Never had such a wonder been seen since the days of the Gothic warrior Walimer, who, according to Eustathius, flashed out sparks from his body, or the ancient philosopher who could never take off his clothes without emitting flames of fire.[1]

Not long after, however, an event occurred that seems to have filled Europe with still greater wonder and awe. It was known as the Leyden experiment. Professor Musschenbroek, who wrote an account of it to Reaumer, can scarcely express in language the agitation and terror into

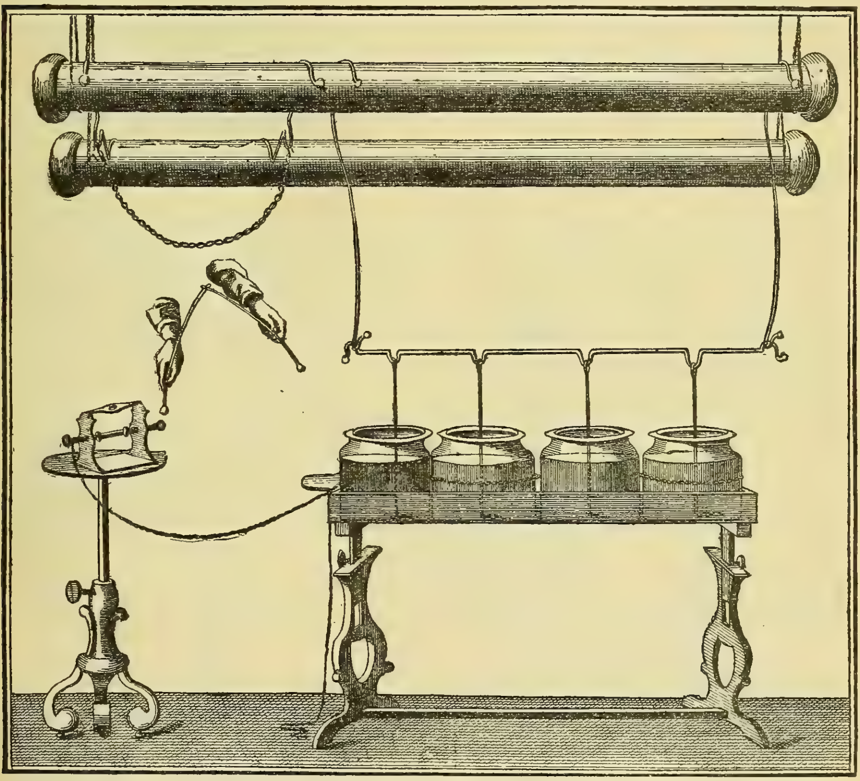


FIG. 6.—BATTERY OF LEYDEN JARS, WITH ACCESSORIES.

which his unheard-of sufferings had thrown him. He had felt the first shock of electricity prepared by human hands, and not the whole kingdom of France, he declared, could induce him to take another. He had been struck in the arms, shoulders, and breast, and two days elapsed before he recovered from the mysterious blow. The professor, in fact, had invented the Leyden jar. He had been endeavoring for some time to inclose electricity in a safe receptacle, from which it could not escape, except with his permission, and at length succeeded in imprisoning the genie in a glass vessel partly filled with water. Suddenly he formed a

[1] Grey seems to have anticipated the experiment. Priestley's Hist. Elect., i, p. 66.

connection between the two surfaces of the jar.[1] The imprisoned electricity sprang through his body and shook him with a wild convulsion. Novelty added its terrors to the unseen assault; his imagination was filled with an indefinite alarm; he shrank from his glass bottle as if it were tenanted by the devil. Yet we soon after find him recovering his spirits, and once more experimenting upon his powerful instrument. The electric jar was soon employed in all the laboratories of Europe, and everywhere terrified philosophers by the vigor of its shock. One lost his breath, and believed that his right arm was forever disabled; Professor Winkler was thrown into convulsions, and had recourse to cooling medicines to avoid fever; Abbé Nollet received a severe blow: his body was bent, his respiration stopped, and he dropped the glass jar in terror. Yet the shock of the Leyden vial soon became the favorite amusement of court and saloon. It was exhibited before Louis XV at Versailles, and a chain of two hundred persons, having joined hands, received at once the mysterious blow. Each was severely shaken, and it was curious to observe, says a contemporary account, how the peculiar temperament of every individual displayed itself in the moment of terror.[2] Soon itinerant electricians wandered over Europe, astonishing the unlearned and the rustics by administering electric shocks from the Leyden jar; and the mysterious machines became familiar to the people as well as to the court.

The jar was improved by coating its sides with a thin metallic covering; its power was increased; it was used in medicine to revive the paralytic, or to open the lips of the dumb; long sparks were drawn from it that resembled flashes of lightning, and that killed unfortunate little birds. A battery of jars was at length invented by Franklin which gave shocks that reminded one of the terrible power of the thunder-bolt; and the whole scientific world felt that it stood on the brink of some unparalleled discovery.

The Franklin was already born, and his name had now grown great in the science.[3] His mind was of a peculiar cast that recalled the vigorous simplicity of the Greeks. He was a modern Solon, a speculative Thales. He had wandered away from Boston,—a printer's apprentice,—and had found employment and success in Philadelphia. From his parents he had received no inheritance, except the noblest,—a spotless example, a healthful constitution, a sane mind; and, after a vigorous struggle and several failures, the philosophic printer had won the respect and the attention of his fellow-townsmen.

He founded schools, libraries, and various useful institutions in his adopted home, and at 45 had become one of the most useful citizens. Still Franklin lived obscure except to his narrow world, and his eminent

[1] Priestley, i, p. 153.
[2] Académie des Science, 1746, p. 7.
[3] Sparks's Life of Franklin, vol. i, p. 152.

powers had won him no general renown. He had, perhaps, pleased himself in his youth with the hope of excelling in letters; he had formed his style by a careful study of Addison; he wrote clear and sensible essays that showed the purity of his taste and the weakness of his fancy; and

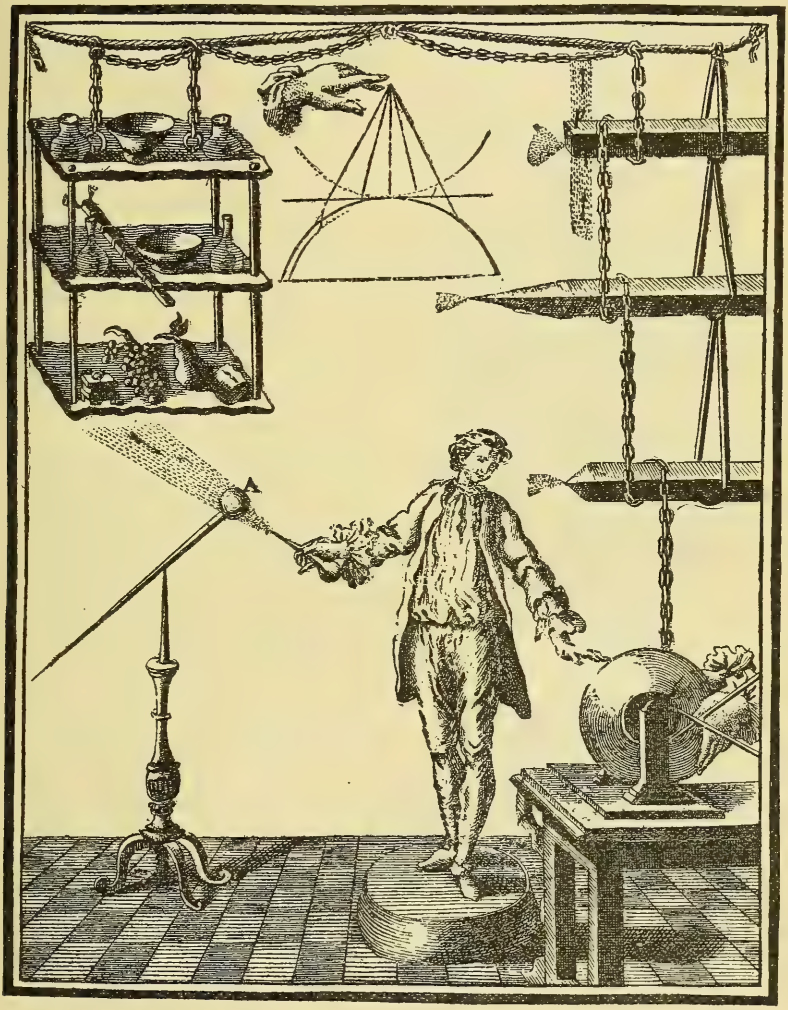


FIG. 7.—ENGRAVING, REPRODUCED FROM NOLLET'S BOOK, SHOWING THE EFFECTS OF ELECTRIC CHARGES UPON EVAPORATION, ETC.

yet, in literature, he had been far excelled in notoriety, if not fame, by his unprincipled companion, Ralph. Franklin's rare humor—the wit of a philosopher—shines out in his "Busy-Body," his "Almanac," his "Ephemera," or his famous "Whistle." He uttered keen apothegms that lived like those of Solon, and sharp satires that want the bitter

hopelessness of Diogenes. But his literature scarcely possessed the shining marks of genius, and was plain, cold, and lifeless. He was an excellent writer, but he was never great.

His genius, like Bacon's, lay in his power of swift induction from moral or physical facts. In morals he was wisest of his contemporaries. He taught young mechanics that "time is money," that "credit is money," and that purity, honesty, and self-respect were better than wealth, luxury, or any other success. His own labors were unceasing; he wrote, toiled, thought incessantly for his fellow-men; he was noted and observed for his modesty and discretion; his acute mind was ever seeking for useful novelty in science and in conduct; and hence, when Franklin came to stand before mankind, covered with his splendid scientific renown and the representative of the new republic that seemed about to receive the classic refinement of a better age, he was received in the courts of Europe as a worthy successor of the philosophers of Athens and Ionia. As Washington appeared before the world clothed in the purity, the probity, the valor of a Fabricius or a Cato, so Franklin was universally compared with the acute sages and philosophers of Greece.

To Franklin electricity owed the most wonderful of all its achievements in the eighteenth century.[1] The obscure provincial observer was led, by an accidental circumstance and his own eager fondness for knowledge, to enter upon the study of the new science. Peter Collinson, a member of the Royal Society, sent over an electrical machine to Philadelphia, and Franklin at once commenced a series of experiments that led to remarkable results. Never, he wrote to Collinson in his first letter, March 28, 1747, had he been so engrossed by any pursuit.[2] All his leisure moments were given to his machine. His fellow-townsmen thronged his rooms to watch his novel researches. His labors were rewarded by constant discoveries, and his wonderful inductive powers soon led him to unfold, in his admirable style, the hidden principles of the science. In 1747 he commenced writing to Collinson, in a series of letters, an account of his researches in electricity. He gave clear directions for the performance of various beautiful or instructive experiments that were wholly new and surprising. He explained the phenomenon of the Leyden jar; he showed how iron points attracted electricity; and, at length, he declared that the lightning and the thunder were produced by the same agent that was inclosed in the mysterious bottle, and he urged the English philosophers to draw down the electricity of the skies by placing iron points upon towers or poles, and thus test the accuracy of his theories. His suggestions, it is related, were received by the Royal Society with shouts of laughter. They refused to print Franklin's

[1] Euler, Dis. de Causa Elect., 1755, p. 27. Idem assernit Franklinus, futuria experimenta animo sagici quasi præmincians. (See p. 132.)

[2] Sparks's Life of Franklin, vol. v, p. 185.

papers in their "Transactions," and they seem to have looked upon his speculations and experiments as scarcely worthy of notice. They thought them the silly dreams of an ignorant provincial.[1]

Fortunately, however, for science and mankind, Collinson was more intelligent, and saw at once the value of Franklin's researches. He published the letters, and they drew the attention of Europe. Buffon read them in France, and persuaded his friend Dalibard to translate them into French; Franklin's rare and beautiful experiments were repeated in Paris; Louis XV and all his court hastened to see them, and were charmed and amazed at Franklin's genius and the wonders of the new science; public lecture-rooms were opened for their performance, and all Paris thronged to the rare exhibition. The letters were translated into many languages, and suddenly the name of the obscure printer in Philadelphia became one of the most renowned in the annals of science. His theories were assailed by the Abbé Nollet and a party of the French philosophers, but they also found many defenders, and a large school of enthusiastic men of science, struck by the vigor of Franklin's genius and the novelty of his discoveries, assumed the name of Franklinists.

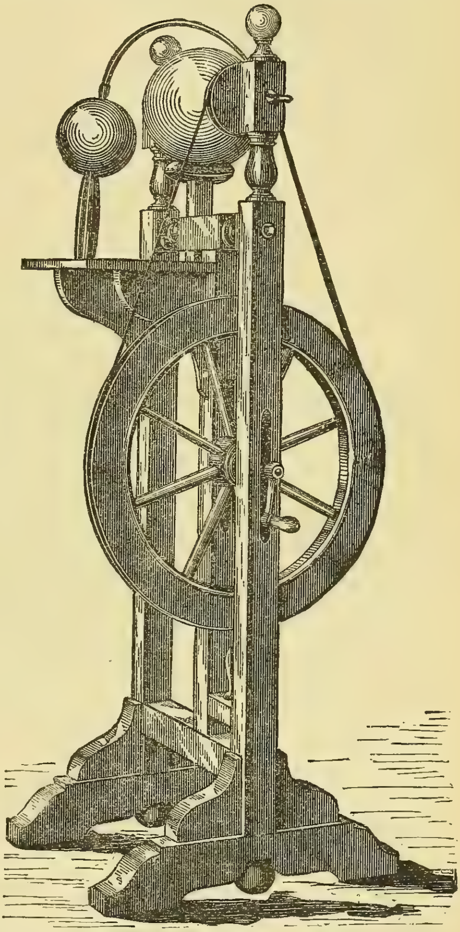


FIG. 8.—ENGRAVING OF BENJAMIN FRANKLIN'S ELECTRICAL MACHINE, THE OLDEST IMPROVED FORM FOR PRODUCING ELECTRICITY FOR EXPERIMENTAL PURPOSES.

Still, however, Franklin's most daring speculation as to the unity of the electricity of the earth and the air, which had awakened the derision of the whole Royal Society, remained untested by experiment, and the philosophers prepared, with doubt and dismay, to attempt its

[1] Sparks's Life of Franklin, vol. v, p. 175.

verification. He felt that his fame must rest upon his success. If he could draw down the lightning from the skies by presenting his iron points to the thunder-cloud, he must attain a renown that would live forever. If he failed, by the incompleteness of his instruments or any unlooked-for accident, he would seem to merit the scorn which European philosophers were prepared to pour upon him.

Philadelphia, too, offered no convenient tower or steeple on which to fix his iron points; while the modest inquirer was probably anxious that his first experiment should be made with no one present to witness his possible failure.[1] His inventive mind suggested a simple expedient. He formed a common kite from a silk handkerchief stretched upon two crossed sticks; on the upper part was placed the iron point; the string was of hemp, terminating in a short silken cord, and at the end of the hempen string hung an iron key. Such was the simple apparatus with which the philosopher set forth from his home, on a cloudy day in June, 1752, to draw the lightning from the skies; to penetrate a mystery upon which ages had meditated in vain. He took his son with him as the only witness of his secret adventure. As the rain was falling he stood under a shed and raised his kite. It was, no doubt, a moment of strong and unprecedented excitement, and we can well imagine that Franklin watched his kite slowly ascending with a keener interest than Etruscan augur or Roman priest had ever felt as he awaited the omen of the gods. A cloud passed over, no trace of electricity appeared; the heart of the philosopher sank with dismay. But suddenly the falling rain made the hempen string an excellent conductor, and Franklin saw that its fibres began to be stirred by some unusual impulse. He applied his hand to the key, and at once drew sparks from the skies. He felt that he had triumphed; but the first thought of his generous nature, no doubt, was how to make his discovery useful to mankind; and one can scarcely avoid lamenting that no vision reached him, in the moment of his victory, of that wonderful instrument with which another American philosopher has girdled the earth and made electricity the guardian of civilization.

Before his own success, Franklin's theory had already been tested and proved in Europe.[2] The French king, Louis XV, was a strong Franklinist, and urged Buffon and the other philosophers to try the experiment of the iron points, according to Franklin's directions. On the 10th of May, therefore, Dalibard erected a bar of iron forty feet long, at Marly, and succeeded in drawing electricity from a thunder-cloud. It should be remembered, too, that the Abbé Nollet had suggested the connection between lightning and electricity before Franklin wrote; and that the idea had arisen in the minds of other philosophers. Yet Franklin could not have been acquainted with their theories, and no one

[1] Sparks's Life of Franklin, vol. v, p. 175.
[2] Gentleman's Magazine, 1752, p. 229.

before him had ever suggested any means of forming a connection with the thunder-cloud. His theory and his method were altogether original.

Again Europe was startled by a novel thrill of wonder and excitement.[1] The electric sparks of the Abbé Nollet and the famous experiment of Leyden sank into insignificance before the sublimity of the new achievement. Franklin, the modest philosopher of half-savage America, snatching the thunder-bolt from the skies with his kite and key, was the wonder of the hour. Kings became his disciples; princes flew kites in summer showers, and repeated the experiments; Europe was covered by a chain of iron points from Paris to St. Petersburg; and the study of the lightning became as universal as in the days of Etruscan superstition.

Franklin was covered with honors. The Royal Society of London, eager to repair its former neglect, elected him a member and awarded him its highest prize. In France, Russia, Germany, he was still more highly honored; he was the most famous of philosophers. From this time, too, until near the close of the century, the science of atmospheric electricity was studied by eager observers. The thunder-cloud was the favorite subject of learned inquiry. Brilliant hopes of further discoveries were entertained that were never fulfilled; and one eminent philosopher fell a victim to the dangerous research.

Professor Richman, of St. Petersburg, had erected an iron rod in his observatory for the purpose of repeating the American experiments, and ventured too near the instrument; a sudden flash descended the conductor, struck him upon the head, and passed through his body. He fell dead against the wall. He is remembered as the martyr of the science. Professor de la Garde, of Florence, was struck down by an unexpected shock, but recovered.[2] Yet danger seemed only to add new interest to the attractive study. Franklin invented his lightning-rod, which was at once employed to protect the homes and the public buildings of Europe and America; and his disciples were everywhere engaged with kites and points in an effort to disarm the thunder-bolt of its terrors.

The thunder-cloud was mapped out and described by countless observers. Lightning from its different forms was given different names.

Franklin and his innumerable disciples began now to extend their researches over the whole domain of nature, and were rewarded by an infinite number of novel discoveries. Everywhere electricity was found to be capable of explaining mysteries that had long seemed supernatural and almost divine, and of offering attractive theories that served to delight and inspire the fancy, even if they did not wholly satisfy the reason. The auroral lights that danced in lovely variety over the icy

[1] Acad. des Sciences, 1752, p. 9.
[2] Gentleman's Magazine, 1753, p. 432.

fields of the north were believed to be electrical.[1] Castor and Pollux, or the baleful Helen, who had wreathed their spectral forms around the masts of Roman ships, now created to be supernatural; the luminous rains, where every drop seemed a ball of fire, or the strange flames that sometimes hovered over armies as they went to battles, were found to be no more mysterious than the Leyden jar; the fearful roar of the thunder was known to be only the echo of the first discharge among the piles of clouds; the electric fire was traced to the water-spout, the whirlwind, or the crater of the volcano; and the triumphant inquiries at length discovered that the round world itself was only a huge electrical machine, and that all its tenants were constantly influenced by the subtle changes of the electric atmosphere.

It was soon observed that the human body was strongly influenced by the electric discharge; the blood ran quicker, the limbs were stirred, the spirits were excited, the intellect aroused;[2] and enthusiastic physicians recorded wonderful cures performed by the aid of electricity. Had not a panacea been discovered? Was not this strange spiritual substance nearly allied to the source of life? The idea, in the last century, excited a new thrill of expectation and awe. Electricity was applied to various forms of disease, and was afterward found successful in effecting a cure. It augmented the circulation of the blood, increased the pulsations, and improved digestion. The paralytic were healed and made to walk again; the feeble and depressed seemed inspired with new hope. The dumb were made to speak, and the blind see.[3] Bertholon, who wrote a treatise on medical electricity toward the close of the last century, relates numerous instances of cure performed by its aid, and the scientific world was full of hope in the efficacy of their new medicament. The electrical machine, for a time, seemed ready to alleviate the worst forms of human woe. So sanguine are men of coming good, so eager to escape from present pain! Yet the pleasing medical dream soon passed away, and it was found that even the Leyden jar was incapable of repairing the ravages of disease, or of amending those evils which men, by their own excesses, so often bring upon themselves. The dissolute noble still fell down in a paralytic fit from which even the skillful electrician, Abbé Nollet, could never awaken him;[4] the uncleanly city was still full of pestilence; the poor hovel communicated its fevers to the palace.

Electricity of to-day, bridled as it is in the hands of the modern scientist and physician, brings forth more ripened fruits. Many ailments are now amenable to the current where other medical agents have failed. The doctor of this age has done much toward bringing electrotherapy to the front rank of medical science.

[1] De la Rive, Treat. Elect., iii, p. 169.

[2] Bertholon, De l'Électricité du Corps Humain, etc., i, p. 94 *et seq.*

[3] Several cases of dumb persons being cured are related in the papers of the time. See Gentleman's Magazine, 1752 and 1753.

[4] Bertholon, i, p. 440. Nollet was the first to electrify the paralytic.

This medical thunder-bolt (electricity) has passed through many vicissitudes, being at one time recognized and employed at the various hospitals, and then again being thrown aside and left for the most part in the hands of the money-making charlatans and quacks; though, as each new important discovery in this science has been reached, medical men's minds have again turned anew to the subject, and interest in its therapeutic properties has been awakened. But as every tide has an ebb and a flood, so the promises of cure; there have followed failures and disappointments which have thrown the usage of this valuable agent into disrepute, to be again, after a time, reborn and nursed into popular favor. It was during a period of two hundred years in which these alterations have been taking place, in the opinions held of the value of electrical treatment and in the frequency of its employment. Men of science have unceasingly been pursuing their investigations into its wonderful mysteries, properties, and possibilities. New successful research on new research has been their patient reward, and to-day we have arrived at an age when practical electricity is making most rapid strides. We shall see, also, the day when the current will be meted out to the suffering in such dosage as our present remedies are meted. The time has arrived, and another electro-therapeutic cloud is hanging over the medical world again. In the past few years special didactic and clinical departments have been added to the regular college curriculum in many of the foremost institutions. The current is once more called into service to aid in the conquering of the many maladies that physicians and surgeons are battling with. It seems that a general desire has been evinced, both by members of the profession and the laity, for a more thorough knowledge of the benefits to be derived from this agent, electricity, and the best means of securing them.

One of the most astonishing discoveries, to the intellect of this age, was the explanation now given of the wonderful properties of the torpedo and the electric eel. They were soon shown to be natural Leyden jars. The torpedo had been noticed by Aristotle and Pliny, and had long been an object of wonder and superstitious dread to the fishermen of the Mediterranean. But its electric power was feeble compared to the startling shocks conveyed by the gymnotus of the lagoons of Cayenne and South America. Humboldt has given a striking description of the vigor of this most famous of the electric fish.[1] He had been anxious to obtain living specimens of the gymnotus, and employed a number of the natives of the country to engage in the singular fishery. The gymnotus lives in the hot bayous of Cayenne, covered by the thick shade of tropical vegetation and hidden in the muddy waters. It is often more than five feet in length, and its electric shocks are so powerful that no living thing ventures to invade its retreat. Even the Indians are afraid to strike it with harpoons or to catch it with a line, since

[1] Travels, vol. ii, pp. 113, 114.

its powerful discharges benumb their arms and drive them away in terror, while the serpent-like agility of the great eel enables it to elude or destroy their nets. Humboldt, together with a party of natives, approached a lagoon inhabited by the electric monsters. He could not conceive how the Indians were to succeed in taking their prey alive; they told him, to his surprise, that they were about to fish for them with horses. A number of mules and horses were collected on the banks of the lagoon, and the Indians drove them, with blows and loud outcries, into the dangerous waters. A strange battle at once began. The electric eels, roused from their torpor, attacked the unfortunate invaders, fastening upon the lower parts of their bodies and giving them a succession of almost fatal shocks. Benumbed, terrified, and fainting, they strove to fly from the dangerous pool, but the Indians drove them back again with wild cries and sharp blows, and the combat was renewed. The huge eels were seen rushing to assail their foes with fresh vigor, and the savages, clinging to the overhanging trees and bushes, forced the horses into the midst of the water; and at length, in a few minutes, the battle was decided, and several of the horses sank and were drowned. "The contest," says Humboldt, "between animals so different in organization, in so strange a place, presented a most picturesque spectacle." It must certainly have been a painful one. And now the victorious eels, having exhausted all their electricity, crept languidly toward the shore, where they were taken with small harpoons fastened to dry lines. So completely was their power lost that the Indians did not receive a shock. Humboldt secured several eels, but little injured, more than five feet long, and he was told that they were often much larger. It is a peculiar trait of the electric animals that they are produced in water,—an excellent conductor,—and that, by some natural provision, they can discharge or retain their electricity at pleasure.

Philosophers now began to explain them with attention, and to form theories as to the source of their action. But the production of animal electricity seems capable of being explained only by those later theories which were soon to enlarge and adorn the science.

Thus the eighteenth century had elevated electricity into one of the most important and attractive branches of knowledge; it was reserved for the nineteenth to apply it practically to the benefit of mankind. In all his brilliant and thoughtful experiments, Franklin had often sighed over their apparent uselessness: he would have been amply satisfied could he have foreseen how powerful an agent his favorite science was destined to become in advancing manufactures and the arts, and in binding nations together by an almost instantaneous exchange of thought.

Galvanism, the next great step in electrical progress, was discovered by Galvani, Professor of Anatomy at Bologna, about the year 1790.[1]

[1] Becquerel, vol. i, p. 83. See report Historique sur les Progrès des Sciences Mathematiques, Paris, 1810, p. 224.

A circumstance so accidental as the slight illness of Madam Galvani gave rise to this important event. Her physician had recommended her to a diet of frog-broth, and several of the animals, prepared for the cook, chanced to lie on a table near an electrical machine. One of Galvani's assistants drew sparks from the conductor, and Madam Galvani was surprised to observe that when he did so the muscles of the frogs were distorted and assumed the appearance of life. She called Galvani to notice the strange circumstance. The experiment was repeated with success, and the philosopher, who knew little of electricity, but was a careful anatomist, believed he was on the brink of discovering the principle of life. He entered with strange ardor upon the new research. He experimented incessantly upon muscles and nerves. At length he found that muscles and nerves were thrown into the singular convulsion by the mere presence of two different metals, and had discovered by accident the principle of galvanism,—the source of the magnetic telegraph or the calcium light.

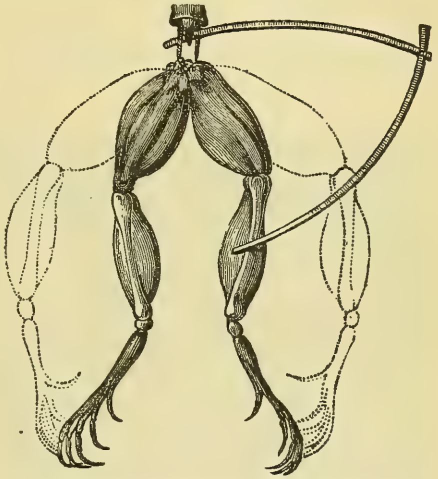


Fig. 9.—Experiment with Frog.

Still, however, Galvani persisted in his scientific delusion that he had unfolded the origin of being. He insisted that the muscles and the nerves created the electric action. He overlooked the effect of the two metals. His disciples were soon numerous, and all Europe was again aroused into excitement by the unparalleled disclosures that philosophy seemed about to make.

Electricity had but lately been drawn down from the clouds; the whole earth was shown to be electric; with one stride more the daring science might unfold the whole mystery of being. But, fortunately for its success, galvanism was taken from the control of its speculative discoverer, and fell into more practical hands. Volta, Professor of Natural Philosophy at Como, an excellent electrician, assailed the theory of his colleague, and showed that the galvanic action came from the two metals, and not from the nerves. A violent controversy raged between the Bolognese school of Galvani and the followers of Volta, and the important question of the origin of life was discussed by the philosophers and the people while Napoleon was preparing to cover Europe with carnage, and while the horrors of the Parisian massacres were yet fresh in every mind. The "reign of terror" which had been commenced in France was about to

extend over all European civilization when the two Italian philosophers were marshaling their disciples in a vigorous intellectual combat. Volta was victorious, and his peaceful triumphs will outweigh a thousandfold, in its beneficial consequences, the disastrous successes of Napoleon.

In the year 1800, a memorable epoch in the history of electricity, Volta announced to the world, in a letter to Sir Joseph Banks, his invention of a wonderful machine. It was composed of alternate sheets or layers of zinc and copper, separated from each other by discs of wet cloth. Two streams of electricity, one negative and the other positive, were found to flow from either pole of the instrument, and its intensity could be increased apparently without limit by enlarging the number of layers. He had invented a voltaic pile. Its form was afterward changed by substituting cups of zinc instead of layers, and Volta formed a beautiful apparatus called "La Couronne de Tasses," the model of all those

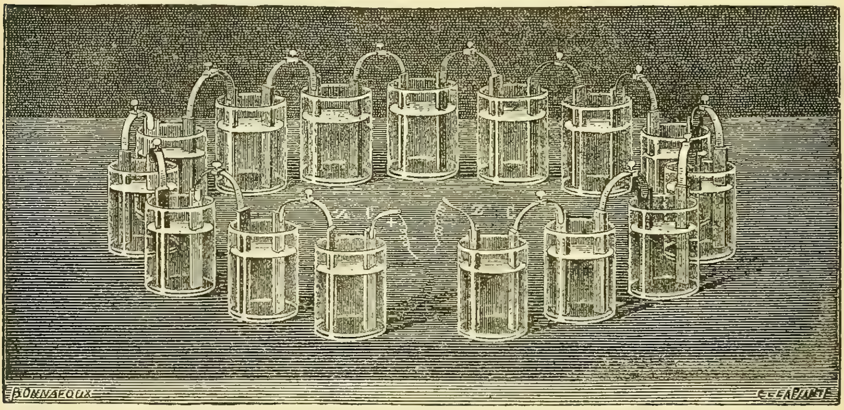


FIG. 10.—COURONNE DE TASSES.

powerful instruments by which the electric current is dispatched on its useful mission from New York to San Francisco, or taught to fathom the once impassable Atlantic. The wonderful vigor of the new agent became at once apparent. The sharp sparks of Franklin's electrical machine, and even the condensed shock of the Leyden jar, so long the terror of philosophers, were found to be faint and inefficient compared with the mighty electric current that flowed with silent strength from one wire to the other of the voltaic pile. Its effect on the human frame revived Galvani's notion of the principle of life. When the hands of the operator were applied to the opposite poles, instead of a sudden shock he found himself held in the grasp of an invisible power. A series of strong convulsions ran through his arms and shoulders. Scarcely could he withdraw his hands and free himself from his captor. If the instrument were applied to the forehead, a brilliant light flashed over the sight, even though the eyes were closed. The glow-worm touched by the current

shone with increased splendor; the grasshopper chirped as if excited by a stimulant. But when the pile was applied to the trunk of a decapitated body, a most horrible and unheard-of phenomenon occurred. Never had such a spectacle been witnessed before since the age of miracles. The dead body rose from its recumbent position; its arms moved as if to strike in its rage objects in its vicinity; its breast heaved, its legs recovered their strength; and life was imitated or renewed in its fearful actions. Such were some of the tales told over Europe of the powers of the voltaic pile.

It was an age of excitement. Napoleon, the young conqueror of Austria and Italy, now ruled as First Consul at Paris. The revolution had died to give place to a reign of war and violent convulsion; and Napoleon, the centre and source of the impending disturbance, yet always eager for scientific novelty, invited Volta to Paris to explain his new instrument.

In 1801, crowned with his peaceful victory, the Italian philosopher visited the republican court. At three meetings in the Academy of Sciences, in the presence of Napoleon and the most famous philosophers of France, Volta lectured upon his incomparable discovery. He was crowned with the highest honors of the institute; Napoleon loaded him with gifts and attentions, selected galvanism as his favorite branch of science, and offered a reward of sixty thousand francs to him who should produce in electricity or magnetism an impulse equal to that which had followed the invention of the voltaic pile, or the startling experiment of Franklin.

Of all the excitements of the age none stirred the intellect more strongly than Volta's theories. The voltaic pile was believed to be the frame-work of the living organization. Napoleon and his philosophers were struck and impressed by the wonderful idea. "It is the image of life!" said the imperious young conqueror, as he once watched some remarkable experiments.[1] The brain was supposed to be an electric pile, the nerves and muscles the conductors of opposing currents, and the slow beating of the heart the effect of their united action. In moments of fierce excitement positive electricity flashed from the eyes and stirred the nerves; in periods of repose the negative controlled the system. Rage, valor, and achievement were positive; submission and cowardice the current from the opposite pole. On the battle-field the fierce conqueror, a terrible voltaic battery, flashed forth his electric currents in fatal profusion; his opponent yielded because his galvanic vigor had declined. The world dreamed wildly over the new machine, and men, with their usual vainglorious presumption, believed themselves gods.

The dreams were swiftly dispelled; but a series of valuable discoveries followed rapidly the invention of the voltaic pile. The first twenty years of the present century were made illustrious by the achieve-

[1] Lardner, vol. i, p. 113.

ments of the new machine. A splendid throng of eminent chemists and electricians sprang up under its influence, and pursued with intense labor and wonderful discoveries the path pointed out by Volta and Galvani. France, England, Germany, Europe, and America united in advancing the science; and the names of Oersted and Ampère, Davy and Wollaston, Berzelius and a great company of men of genius, scarcely inferior to their leaders, won a renown in their peaceful pursuit that shines with a softened glory amidst the fierce military excitement of that troubled age. Of these men Humphry Davy was perhaps the most conspicuous. Poet, thinker, philosopher, Davy finally concentrated all the great powers of his intellect upon the study of the voltaic pile. He used it to unfold the deepest mysteries of nature. He discovered its wonderful strength, and developed all its resources. Suddenly the most solid and least fusible substances in nature were found to melt away into gases before the steady flow of the galvanic current. Water resolved itself into its gaseous elements. The alkalies liquefied and left behind them their metallic bases. New metals were discovered whose existence had never been suspected. A tremendous heat was produced that burned gold and silver as easily as paper, and that even fused the firm platinum.[1] A magnificent light was produced by burning potash, such as man had never created before. The diamond was melted; the various earths dissolved; the composition of the air investigated; and it was believed that all the geölogical changes of the surface of the globe were to be attributed to galvanic action. In fact, chemistry became almost a new science under the reforming influence of the voltaic pile; and the brilliant researches of Sir Humphry Davy and his associates astonished their age by their singular novelty and their rare value to the artist and the machine.

Thus the dawn of the nineteenth century might seem to have been almost consecrated to the study of the electric forces. Yet it was also a period of unusual intellectual excitement; and while Davy, Oersted, Ampère, and their associates were startling the world by a succession of wonderful discoveries, the literary atmosphere resounded with the strains of a new school of poetry. Byron, Moore, Coleridge, Wordsworth, and Keats poured forth the language of passion or of reflection to countless readers, and literature united with science in aiding the progress of thought.

At length, in 1820, Oersted, by a remarkable experiment, found the indissoluble union between magnetism and electricity. The magnet, as well as the electron, had long been one of the chief mysteries of nature. Thales had observed its attractive properties, and had supposed that it was endowed with a soul. The Chinese and the Arabs knew that the magnetized needle invariably pointed to the north, and had employed it to guide their journeys by land or sea. Its variations were observed by Columbus, and studied with attention by the early Dutch and English

[1] Lardner, i, p. 133.

navigators. Its connection with electricity had for some time been suspected, and Franklin magnetized a needle by an electric discharge.

But it is to Oersted that we owe the grand experiment by which it was shown that the motion of the magnet depended upon galvanic currents. He showed that a magnetized needle was deflected or controlled by the passage of the electric fluid along a wire. The discovery produced a new ardor in every scientific mind. Ampère, Arago, Davy, Faraday, and Henry enlarged upon the thought; powerful magnets were formed by passing the voltaic fluid through a wire bound in spiral folds around an iron bar, and the principal ones at length discovered upon which rests the crowning achievement of electricity,—*the magnetic telegraph!*

We have now traced, though very briefly, the progress of knowledge of electricity, from the germ of the science which lay hidden for thousands of years in amber, like the insects so often found in that substance,—and yet unlike them, for it possessed immortality,—up to the first practical application of that knowledge to human use and benefit. The lightning had been caged. The mighty force, which since the creation of mankind had aroused but feelings of awe and terror, could now be confined and examined, or diverted at will from its path of destruction. The wise men of the eighteenth century had captured the electrical Pegasus; it remained for the wiser men of the nineteenth century to yoke him to the plough.

It is the most poetical of the sciences, as well as the most practical. Its future is full of promise, and no one can safely affirm that it may not yet achieve discoveries more wonderful than any in the past, and produce a still more beneficial effect upon the progress of man. Yet its earlier cultivators can never be forgotten, and the gratitude of their race must always attend those laborious intellects whose endless toil snatched the thunder-bolt from the skies and made it the useful servant of modern civilization.

Electrical Measurement.

Twenty-five years ago the experimental sciences of electricity as well as magnetism were, in great measure, mere collections of qualitative results, and, in a less degree, of results quantitatively estimated by means of units which were altogether arbitrary. These units, depending as they did on constants of instruments and conditions of experimenting which could never be made fully known to the scientific public, were a source of much perplexity and labor to every investigator, and to a great extent prevented the results which they expressed from bearing fruit to the furtherance of scientific progress. Now, happily, all this has been changed. The absolute system of units introduced by Gauss and Weber, and rendered a practical reality in England by the labors of the British Association Committee on Electrical Standards, has changed experi-

mental electricity and magnetism into sciences of which the very essence is the most delicate and exact measurement, and enables their results to be expressed in units which are altogether independent of the instruments, the surroundings, and the locality of the investigator.

The record of the determinations of units made by the members of the committee, for the most part of the methods and instruments which they themselves invented, forms alone one of the most interesting and instructive books[1] in the literature of electricity, and, when the history of electrical discovery is written, the story of their work will form one of its most important chapters. But besides placing on a sure foundation the system of absolute units, they conferred a hardly less important benefit on electricians by giving them a convenient nomenclature for electrical quantities. The great utility of the practical units and nomenclature which the committee recommended soon became manifest to every one who had to perform electrical measurements, and has led, within the last few years, to their adoption, with only slight alterations, by nearly all civilized nations. Although it is only five years since the recommendations[2] of the Paris Congress of Electricians were issued, they have been almost universally adopted and appreciated by those engaged in electrical work, and have thus begun to yield excellent fruit by rendering immediately available for comparison, and as a basis for further research, the results of experimenters in all parts of the world.

But in order that the full benefit of the conclusions of the Paris Congress may be obtained it is essential, in the first place, that convenient instruments should be used; adapted to give directly, or by an easy reduction from their indications, the number of ampères of current flowing in a particular circuit, and the number of volts of difference of potential between any two points in that circuit. To be generally useful in practice these instruments should be easily portable and should have a very large range of sensibility; so that, for example, the instrument which suffices to measure the full potential produced by a large dynamo-electric machine may be also available for testing, if need be, the resistance of the various parts of the armature and magnets by the readiest and most satisfactory method, namely, by comparing, by means of a galvanometer, a high resistance of difference of potential between the two ends of a known resistance joined up in the same electrical circuit. In like manner the ampère measure should be one that could be introduced without sensible disturbance into a circuit of low resistance to measure either small fractions of an ampère or the whole current flowing through a circuit containing a large number of electric lamps. These conditions are more or less fulfilled by a large variety of practical instruments recently patented by different inventors.

[1] Report of the British Association Committee on Electrical Standards. Edited by Professor Jenkin, F.R.S.

[2] See Appendix, in book on Absolute Measurements in Electricity and Magnetism, by Andrew Gray, M.A., F.R.S.E., for practical units, as adopted by the British and Paris Associations. London: Macmillan & Co.

Almost every branch of science nowadays has its own language, made up of its technical terms, which in time become absorbed even into general speech. This is already fast becoming the case with the language of electricity. Ampères and volts and ohms are no longer possessed of meaning only to the initiated, but are taking their place among such every-day standards as pounds and gallons and inches. Although this chapter has none of the pretensions of a treatise, it is my aim to devote it to a plain statement of the principles of electrical measurement and the uses of the most important forms of the galvanometer.

There is no force in nature more subject to the inevitable laws of the great mother than electricity; and many of these laws, and these measurements dependent upon them, are so simple as with little study to be readily mastered. Just as in the ordinary arithmetical standard we employ weights and measures, so we may in the application of electricity employ various measurements for various purposes.

As, also, we commonly employ suitable instruments and apparatuses in weighing and measuring tangible substances, using scales or balances for those bought and sold by weight, tape-measures and miles for measurements, and clocks and watches to mark the advance of time, so we find it essential, in the valuations and comparisons of electricity, to use suitable instruments.

These instruments are named galvanometers, and are used to measure, compare, and estimate many of the different properties and magnitudes of electricity. By their aid we may readily ascertain and compare the working strength and value of electric currents, the resistance which electro-magnets, wires, and other conductors offer to the passage of the current, the electro-motive force or initial power, and the resistance of batteries, etc. Farther on we shall speak in full of the galvanometer, etc.

Definitions of Electrical Terms and Units.—In order that the galvanometer be clearly understood, as well as when, why, and how to use it, it is proper that at the outset we should at least have some comprehension of the meaning of the terms commonly used in expressing the different properties, magnitudes, functions, and relations of electricity and electrical conductors, and of the units which indicate the value of such properties.

In the part of this work on "General Remarks upon Batteries," I have already given in detail, and shown by means of experimental illustration, some of these electrical terms, such as electro-motive force, potential, resistance, joint resistance, internal resistance, etc.

Units of Electrical Measurements.—We know now, by what has been seen, that the batteries by which electricity is developed, the conductors by which it is transferred, the instruments by which it is made useful, and the electric current itself have certain properties, magnitudes, or qualities which it is often necessary to measure in order that their working value may be properly estimated.

In order to make such measurements and to state their results, it is essential that there should be some standard terms or units, which, when expressed, will convey to the mind definite ideas, precisely as in measuring a distance, etc.

Furthermore, when one substance has several properties or magnitudes, a different system of measurement is required for each magnitude; for, as in a cubic block of wood we should measure one of its sides by superficial measure, its contents by cubic measure, and its weights by still another system, and would state the results differently in each case, so the different electrical magnitudes have their own opposite and separate units in which the results are expressed.

Sometimes it is found that the results of certain measurements are obtained by reference to several different magnitudes; as, for example, when the time is taken of the speed of a horse, or a locomotive, we take the length of the distance traversed and the time consumed in traveling that distance, and so calculate the velocity by reference to both space and time. In certain electrical measurements we find it necessary to resort to the same process, and to combine different units to obtain a definite result.

The names of distinguished electricians and scientists have been given to the practical electrical units. Thus the unit of electro-motive force is called the "volt," from Volta; and the unit of resistance the "ohm," after Ohm, the German physicist and mathematician; while the unit of current-strength is named the "ampère," after the French philosopher.

An Analysis of the Arithmetical Electrical Terms.—Space is the lineal distance from one point to another.

Time is the measure of duration.

Force is any cause of change of motion of matter. It is expressed practically by grammes, volts, pounds, or other units.

Resistance is a counter-force or whatever opposes the action of force.

Work is force exercised in traversing a space against a resistance or counter-force. Force multiplied by space denotes work as foot-pounds.

Energy is the capacity for doing work, and is measurable by work units.

Mass is quantity of matter.

Weight is the force apparent when gravity acts upon mass. When the latter is prevented from moving under the stress of gravity its weight can be appreciated.

Physical and mechanical calculations are based on three fundamental units of dimension, as follow: the unit of time, the second,—T; the unit of length, the centimetre,—L; the unit of mass, the gramme,—M. Concerning the latter, it is to be distinguished from weight. The gramme is equal to one cubic centimetre of water, under standard conditions, and

is invariable. The weight of a gramme varies slightly with the latitude and with other conditions. Upon these three fundamental units are based the derived units,—geometrical, mechanical, and electrical. The derived units are named from the initials of their units of dimensions, the C. G. S. units, indicating centimetre, gramme, second units.

In practical electrical calculations we deal with certain quantities selected as of convenient size, and as bearing an easily-defined relation to the fundamental units. They are called practical units.

The cause of a manifestation of energy is force; if of electro-motive energy,—that is to say, of electric energy in the current form,—it is called electro-motive force (E. M. F., or simply E.), or difference of potential (D. P.). What this condition of excitation may be is a profound mystery, like gravitation and much else in the physical world. The practical unit of electro-motive force is the *volt*, equal to one hundred millions (100,000,000) C. G. S. units of electro-motive force. The last numeral is expressed more briefly as the eighth power of 10, or 10^8. Thus the volt is defined as equal to 10^8 C. G. S. unit of electro-motive force.

This notation in powers of 10 is used throughout C. G. S. calculations. Division by a power of 10 is expressed by using a negative exponent, thus 10^8 means $\frac{1}{100000000}$. The exponent indicates the number of ciphers to be placed after 1.

When electro-motive force does work, a current is produced. The practical unit of current is the ampère, equal to $\frac{1}{10}$ C. G. S. unit, or 10^1 C. G. S. unit, $\frac{1}{10}$ being expressed by 10^1.

A current of 1 ampère passing for one second gives a quantity of electricity. It is called the *coulomb*, and is equal to 10^1 C. G. S. unit.

A coulomb of electricity, if stored in a recipient, tends to escape with a definite electro-motive force. If the recipient is of such character that this definite electro-motive force is 1 volt, it has a capacity of 1 *farad*, equal to $\frac{1}{1000000000}$, or 10^9 C. G. S. unit.

A current of electricity passes through some substances more easily than through others. The relative ease of passage is termed conductance. In calculations its reciprocal, which is resistance, is almost universally used. A current of 1 ampère is maintained by 1 volt through a resistance of 1 practical unit. This unit is called the ohm, and is equal to 10^9 C. G. S. unit.

Sometimes, where larger units are wanted, the prefix *deka*, ten times; *heka*, one hundred times; *kilo*, one thousand times; or *mega*, one million times, is used,—as *dekalitre*, ten litres; *kilowatt*, one thousand watts; *megohm*, one million ohms.

Sometimes, where smaller units are wanted, the prefix, *deci*, one-tenth; *centi*, one-hundredth; *milli*, one-thousandth; *micro*, one-millionth, are used. A *micro-farad* is one-millionth of a farad.

Practical Units.—Electro-motive force is measured in volts. A

volt is very nearly the pressure yielded by a certain standard galvanic cell, usually the Daniell, to be described later in this work. The term has also a very accurate mathematical signification.

The "volt" is the unit of electro-motive force, and has very nearly the same value as a single cell of the Daniell battery. Its precise value is 9268 of a Daniell cell in good condition; in other words, the Daniell cell is equal in electro-motive force to one volt and seventy-nine thousandths—1.079. The volt is equivalent to the electro-motive force required to produce a current of the strength of 1 ampère in a circuit having a total resistance of 1 ohm.

The electro-motive force of most of the gravity batteries is almost the same as that of the Daniell, and the electro-motive force of the Leclanché cell is 1.481, or one volt and four hundred and eighty-one thousandths.

OHM'S LAW AND ITS EXPLANATION.

The law showing the relation between electro-motive force, resistance, and current was enunciated by Dr. G. S. Ohm, and is known as Ohm's law. This is the fundamental law of electricity in motion.

Consequently, there are three things about any electric current to be known, namely: its electro-motive force, or pressure; the resistance which it encounters; and the strength of the current, which depends upon these.

We measure steam- or water- pressure in pounds per square inch, heat by thermometric degrees, distances by feet and inches, and so on.

The Ohm.—The standard unit of resistance, which we call the "ohm," may be defined as a resistance about equal to that offered by a wire of pure copper one-twentieth of an inch in diameter and two hundred and fifty feet long, or it may be compared to one-sixteenth of a mile of copper wire, No. $4\frac{1}{2}$ Birmingham wire gauge, which is twenty-three hundredths of an inch, or nearly a fourth of an inch in diameter. It is also approximately equal to a piece of No. 35 copper wire between seven and eight feet long. A mile of No. 12 galvanized-iron wire has an average resistance of about 32 ohms.

The mark which may usually be found stamped on the base of a relay denotes the resistance of the coil from one binding-screw to the other. If, for example, we have a relay marked 100 ohms, we know that that is the measured resistance of the two spools, and that it is equal to about three miles of No. 12 galvanized-iron wire.

THE OHM'S LAW-GIVING SPECIFIC VALUE.

Thus, the strength of current in ampères flowing through a circuit is equal to the number of volts of electro-motive force divided by the number of ohms of resistance in the entire circuit. The strength of current is ascertained by taking the electro-motive force in volts and

dividing that number by the total resistance of the circuit, including that of the battery, wires, and instruments, in ohms. The result will be in ampères, or fractions thereof.

Let us follow this problem out. A battery having an electro-motive force of 50 volts and an internal resistance of 75 ohms is connected in circuit with a galvanometer having a resistance also of 10 ohms. The total resistance in the circuit is that of the battery, galvanometer, and wire added together, *i.e.*, 160 ohms. To find the strength of current we divide the 50 volts by the 160 ohms, which gives us a quotient of 0.3125 ampère, or 312½ milliampères.

Therefore, if we know the electro-motive force and resistance of any circuit, we can easily figure out the strength of current. On the same principle, knowing the electro-motive force in volts of a battery, and the current in ampères produced thereby in a given circuit, we can ascertain the resistance of that circuit, including that of the battery, by dividing the electro-motive force by the current. Likewise, the value of electro-

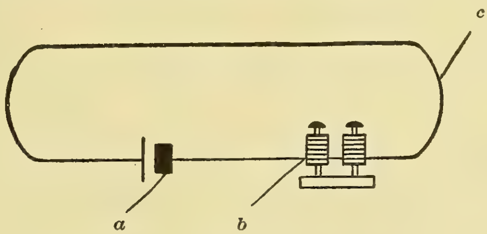


FIG. 11.
a, battery; *b*, electro-magnet; *c*, connecting wire.

motive force may be obtained if we know that of the current and of the total resistance of the circuit; for if we multiply the resistance in ohms by the current-strength in ampères, we find the value of the electro-motive force in volts.

The Ampère.—The unit of current-strength was, until very lately, called a "weber," but is now called the ampère, after the French physicist of that name. The ampère may be defined as the strength of a current produced in a circuit having a total resistance of 1 ohm by an electro-motive force of 1 volt.

Let us explain it in the following way: If a circuit consisting of one cell of a battery, an electro-magnet, and the necessary connecting wires, as in the above diagram,—the battery, we will suppose, having an electro-motive force of 1 volt and an internal resistance of $\frac{1}{3}$ ohm,—the electro-magnet and connecting wires also have a resistance of $\frac{1}{3}$ ohm each, making a total resistance of 1 ohm in circuit.

The current flowing in this circuit will have a strength of 1 ampère. A milliampère is one-thousandth of an ampère, and is made use of in computing currents of comparatively feeble strength. This last unit of current-strength is used in medical electricity.

To recapitulate in briefer terms, electro-motive force means electrical pressure. Resistance has its obvious meaning. Electro-motive force is not measured in pounds per square inch like steam- or water- pressure, but in volts; and a volt is the pressure given by one standard cell.

Resistance is measured in ohms, and an ohm answers to the resistance offered by four hundred and sixty feet of ordinary telegraph-wire. Approximately, strength of current is measured in ampères. Speaking of a water-wheel, we say we need current flowing at the rate of so many gallons per minute to drive it; speaking of an electric lamp, we say we need a current of from 1 to 50 ampères to keep it glowing. The term "*coulomb*", is a unit current or ampère which transmits the unit quantity of electricity in one second. The unit of electric quantity is called a coulomb; and just as the unit flow of water through a pipe might be taken as that which allowed one gallon of water to pass any point in the pipe during one second of time, so the ampère is the strength of current—the rapidity of flow—which allows 1 coulomb to pass any point in the circuit during one second; so that if a constant current of 1 ampère has been flowing for one hundred seconds in a circuit, then we know that 100 coulombs of electricity have passed any point in the circuit during that time. This unit is far less employed in practice than any of the others, but it may be, in the end, the most familiar of all; for, as electro-therapists, we must sooner or later realize the necessity of measuring the quantity of electricity we give our patients, just as we do any other remedy in our pharmacopœia; and when the electric light comes into more general use in dwellings we shall pay for our electrical supply at so much per thousand coulombs, as we pay for gas at so much per thousand cubic feet.

Tables of Resistances and Conductivity.—It has been already stated that the resistance of a conductor depends upon its dimensions and the matter that composes it. Matthiessen, taking copper, found the following values :—

Metal.	Specific Resistance.
Silver,	0.77.
Gold,	1.38.
Aluminium,	2.29.
Zinc,	2.82.
Iron,	5.36.
Tin,	6.76.
Platinum,	7.35.
Lead,	9.96.
German silver,	10.09.
Antimony,	18.07.
Mercury,	47.48.
Bismuth,	64.52.
Graphite,	1106.00.
Gas-carbon,	2037.00.

From this table we learn that, of all metals, silver offers the least

resistance. We can easily arrange a table of conductivity by taking the reciprocals of the foregoing :—

Metal.	Specific Conductivity.
Silver,	100.00.
Copper,	77.43.
Zinc,	27.39.
Iron,	14.44.
Platinum,	10.53.
Lead,	7.77.
Mercury,	1.03.
German silver,	7.67.
Graphite,	0.0693.
Gas-coal,	0.0386.

The relative conductivity of the principal liquids used in batteries may be seen from the following values found by Becquerel (conductivity of silver = 100,000,000) :—

Liquid.	Conductivity.
Copper sulphate (a saturated solution),	5.42.
Ordinary salt " " "	31.52.
Copper nitrate " " "	8.99.
Zinc sulphate " " "	5.77.
20 c.c. of H_2SO_4 in 220 c.c. water,	88.68.
Nitric acid,	93.77.

Resistances of liquids at different stages of concentration may be seen from the following table by Wiedemann (resistance of platinum = 1) :—

Sulphuric Acid Contained in 100 C.c. Water.	Resistance.
3.7 grammes,	499,000.
5.9 "	283,500.
11.42 "	147,200.
22.82 "	88,070.
45.84 "	79,560.
74.83 "	108,300.
183.96 "	508,000.

With salt solutions the resistance diminishes as the amount of salt increases, the conductivity of pure water being very small. The behavior of sulphuric acid is peculiar. Up to a certain point resistance diminishes with the increase of concentration, but beyond this point resistance increases with further concentration.

The influence of temperature upon a liquid may be seen from the following table, after Wiedemann. The liquid tested was formed by solution of 187.02 grammes of copper sulphate in 1000 cubic centimetres of water :—

At 20.2° C.,	the resistance = 1,907,000.
At 26.2° C.,	" " = 1,715,000.
At 37.5° C.,	" " = 1,419,000.
At 51.5° C.,	" " = 1,163,000.
At 60.0° C.,	" " = 1,047,000.
At 75.6° C.,	" " = 894,000.

The resistance diminishes as the temperature increases, a result which is exactly opposite to what occurs with metals. Müller found the following values for copper wire at different temperatures :—

At 21° C., ...	the resistance	=	864.
At a dull-red heat, ...	"	"	=2100.
At a red heat, ...	"	"	=2450.
At a bright-red heat, ...	"	"	=3300.
At a white heat, ...	"	"	=4700.

When the wire was again cooled to 21° C. its resistance was 910.

Conductivity for carbon increases with the temperature, thus agreeing with the action of liquids. Professor Ayrton thinks this seems to indicate that carbon may be a compound, and not an element. Mercury follows the other metals; that is, conductivity decreases and resistance increases with temperature.

The Wheatstone Bridge is the differential resistance measurer. This instrument is fully described by Wheatstone, its inventor, in the "Transactions of the Royal Society," 1843. This bridge, or also called electrical balance, is usually constructed in this manner: Upon a piece of well-seasoned board, *M*, are placed three strips of thin brass or copper about half an inch in width, which are fastened as shown at *A*, *B*, and *D*, a break being left at both ends of *A*, and also between *B* and *D*. From *B* to *D* a thin German-silver wire, which should be uniform in thickness and free from flaws, is stretched and soldered to the brass or copper strips at each end. Underneath this wire a paper scale, accurately divided into a thousand parts, is placed. Should the length of the wire be, as is usually the case, a metre, the divisions will, of course, be millimetres, but there is no necessity for the wire to be of any definite length; all that is required is that it should be accurately divided, the measurements to be taken from it being not absolute, but comparative. German-silver wire is usually employed because its conductivity is but little affected by variations in temperature. An ebonite block, provided with a metal pin, is made to slide along the board and is connected with a wire, the other end of which may be attached to one pole of the battery or to a galvanometer. The metal pin is usually provided with a spring, so that it may be pressed down upon the wire or not, at pleasure, thus forming a ready means of making or breaking the circuit. To the middle of the strip of copper, *A*, a binding-screw is attached, and to this is fastened one of the battery wires. Binding-screws are also attached to the two ends of *A*, and to the adjacent ends of the side-strips *B* and *D*. In these binding-screws strips of wire, r' and n_3, can be placed so as to fill up the breaks between the side-strips and the ends of the longitudinal strip. *A*, *B*, and *D* are connected with a delicate astatic galvanometer, *G*. This being the construction of the Wheatstone bridge, its mode of action will be, perhaps, better understood by the following diagrams and demonstrations :—

It was found necessary, in experimenting with thousands of miles of cable or insulated wires, to adopt some standard point, in order to ascertain exactly the resistance of the whole. The matter was put into the hands of a committee of the British Association, who determined that an English mile of pure copper wire, No. 16, should be the B. A. unit; they further constructed a wire of silver and platinum, because it was little affected by temperature, which they deposited as the standard of comparison, and this length of wire they estimated in figures to be 13.59 of the length of the copper wire. Bobbins upon which hundreds and thousands of miles of copper wire, No. 16, would have to be wound would be too bulky and cumbersome to manage; it has, therefore, been arranged that German silver, an alloy of about 60 parts of copper with a fraction of lead, 25 of zinc, and 15 of nickel, should be employed, because it has about thirteen times less conducting power than the same-sized copper wire; consequently the standard unit would be represented as follows: B. A. unit of German-silver wire equals 13.59 of an English mile. The bobbins having 13.59 of an English mile of German-silver wire wound upon them represent, therefore, a resistance equal to one mile. The following physical law is the outcome: The resistance of a conductor of any given metal is *directly proportional to its length, and inversely proportional to its thickness*, or cross-section.

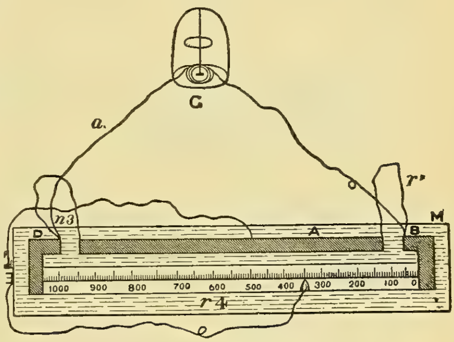


FIG. 12.—WHEATSTONE BRIDGE.

In order to demonstrate clearly the practical value of the Wheatstone bridge, inasmuch as it is so often difficult to thoroughly comprehend its construction and the principles underlying it, I append the following diagrams, with a brief demonstration[1] :—

For the sake of simplicity the brass bands and brakes only are shown. The galvanometer is supposed to be resting in the middle of the board, the battery on the right, and the connecting-key on the left.

For the sake of discussion, it is supposed that the current coming from the battery, *Ba*, is represented by twelve parts; these, on arriving at *P*, split or divide into equal parts; six go in the direction, *A′*, and six in the other, *A*.

The two currents represented by arrows both pass through equal

[1] These diagrams are made from the Wheatstone bridge used for demonstrating a broken cable at the Polytechnic of London by Mr. Becker. The bridge is constructed eight feet long and two feet eight inches wide; the lozenge-shaped brass plates are one and one-half inches wide. There are four brakes with binding-screws, and, by using bobbins upon which the B. A. unit of German-silver wire was wound, the students were made to understand that each bobbin represented a mile of pure copper wire, No. 16.

resistance coils, A', A, and the respective currents might pass direct to the key, K (where contact is made or broken), and through that to the other pole of the battery; but the currents are partially arrested by the equal resistance coils, B', B, and a portion of the currents is forced into or divided into the galvanometer, $G\ N$.

The use of the coils, or any other resisting matter, on the other side of the galvanometer is to force, or rather gently to impel, a part of the current into the galvanometer; because if this were not done the deflection would be so small that it might be barely perceptible.

Let us say, for the sake of discussion, that 2 parts pass to the galvanometer from Q and 2 parts from S; such currents, coming in opposite directions, must oppose each other's progress through the galvanometer, and therefore the needle of the latter does not move.

We have only now to suppose that $4 + 2 = 6$ proceed from Q to

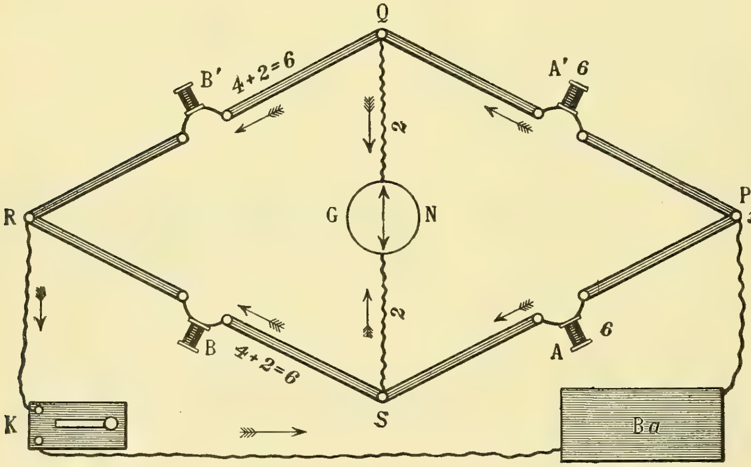


FIG. 13.

R, and $4 + 2 = 6$ by S to R; the two added together make 12, the original quantity started with, which proceeds through the key and connecting wire to the other pole of the battery, Ba.

The second diagram consists of two parts, viz., Part I and Part II, and it is recommended that the latter be traced on tracing-paper and placed upon the former. The current again is represented by 12 parts. The resistance of the coil at A', Part I, being less than A, Part II, the greater part of the current—say, 8 A' parts—goes through the former, and 4 A through the latter, consisting of a piece of copper wire and a resistance coil; therefore, returning to Part I, the current going by A' through Q to $G\ N$, the galvanometer needle, forms, at the point Q, a greater partial current (say, 3 parts) than the current going by A, Part II, which divides at S, and is represented by, say, $1\frac{1}{2}$ parts; therefore, the current that deflects the galvanometer is the greater going by Q, Part I, and marked 3;

consequently, it amounts in imagination to a struggle between the current going by Q, Part I, represented by 3 parts, and the current going by S, Part II, or $1\frac{1}{2}$ parts. The issue cannot be doubtful; the greater

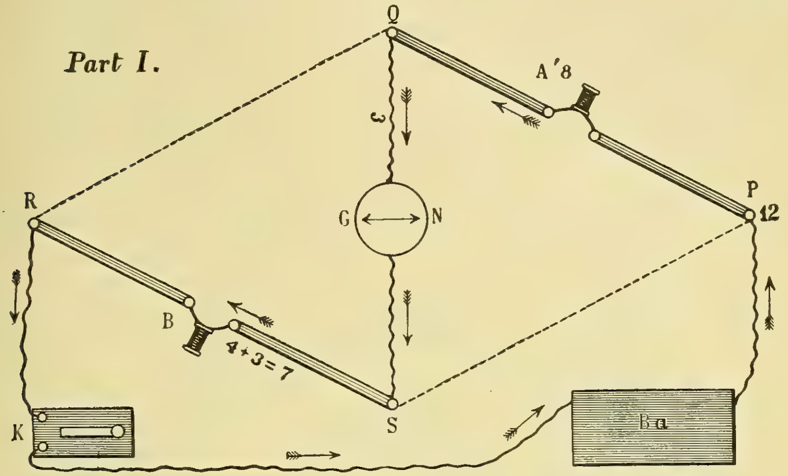


FIG. 14.

current, 3, overcomes the lesser, $1\frac{1}{2}$. In Part I, $4 + 3 = 7$ go by B, and in Part II 5 go by B'; and if the two are added together they again make the 12 parts, which, as before, travel through the key and connecting wire to the other pole of the battery, *Ba*.

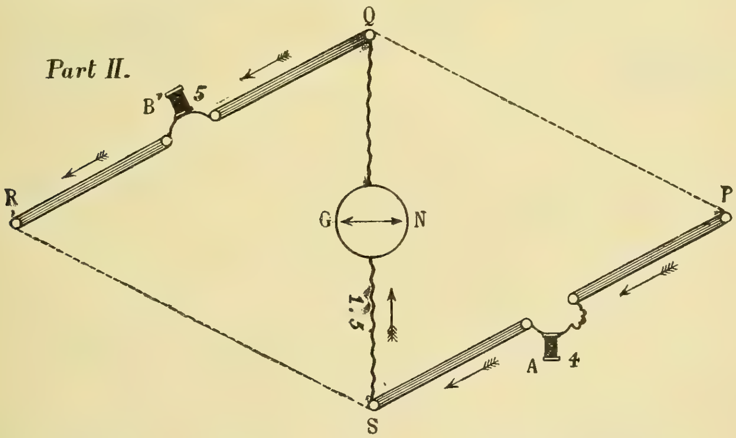


FIG. 15.

The next diagram (Fig. 16) explains the use of the bridge for comparing the conductivity or resistance of wires of different metals or different lengths of same wire. The lower part (A to B) of the bridge marked in dotted lines is not required, its place being filled by a long German-silver wire stretched from P to R, and provided with a scale

divided, say, into 20 parts; on this the galvanometer screws, the other screw of the galvanometer being connected with *Q*.

In this case we are to suppose it is being used to ascertain the relative lengths of wire of the same metal, diameter, and conductivity. The clip, *S*, has been moved from the centre, *C*, to No. 13.334 on the scale painted below the wire, *P* to *R*. The clip has been moved to 13.334, or until the galvanometer is at rest; this quantity, 13.334, is double that of *R* to *S*, therefore the resistance at *B′* is shown to be half the resistance at *A′*, because *A′* has two coils or two miles of wire, and *B′* one mile; so that it is shown, without any previous knowledge of the absolute length of the two coils at *A′* (the wire under examination), that it is double the length of the known quantity, one mile at *B′*, because the scale from *R*

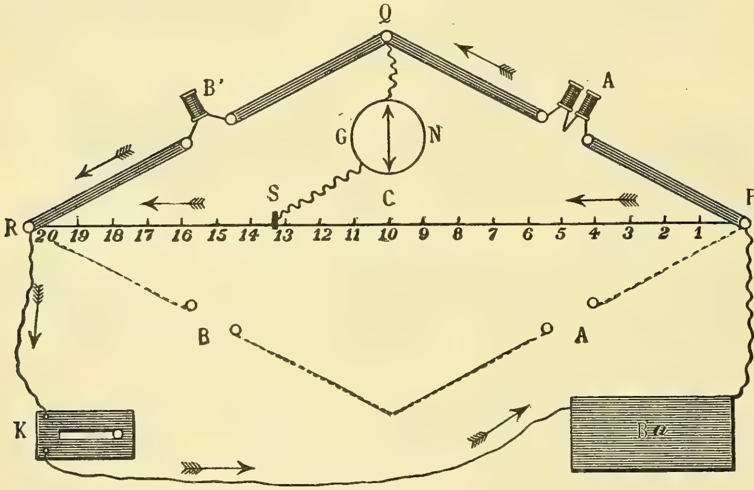


FIG. 16.

to *S* is 6.666, and that from *P* to *S* 13.334, and if one is added to the other they make up the whole scale of 20.

THE GALVANOMETER.

It is of the highest importance that the electro-therapist shall be able, during the course of an electrical *séance*, to see at a glance in what direction the currents are passing, and measure their strength. For this purpose a galvanometer of some form or make is necessary.

One of its most important functions is the testing and measurement of the resistance of line wires, instruments, coils, batteries, and insulation, and for many other similar purposes.

Its operation depends upon the action of the two forces—electricity and magnetism—and, though galvanometers are made in many forms and are used in several different ways, they are all based on the fundamental fact that a magnetic needle is deflected or turned aside from its

natural position by the passage of a current of electricity in a conductor placed parallel to it.

When a steel needle is magnetized and delicately pivoted at its centre, so that it is free to move horizontally, every one knows that it will set itself north and south, a common example being the ordinary compass-needle.

This action of the needle is due to the influence of the earth, which is itself an enormously large and strong magnet. All magnets attract the opposite poles and repel the similar poles of other magnets. For instance, the north pole of the earth attracts the south pole of the magnetic needle, causing the needle to point north and south as it does.

Among those who had studied most deeply the phenomena of galvanic electricity was Hans Christian Oersted,—a Danish physicist and professor of physics in the University of Copenhagen,—of whom we have already spoken in our "historical sketch." Oersted's researches led him to suspect the identity of magnetism with electricity, but for a long time no means of experimentally proving the fact revealed itself. The expedient had been tried, but without results, of placing the two poles of a battery, as highly charged as possible, in a parallel line with the poles of a magnetic needle. In one of the reports of the Smithsonian Institute the story of his discovery is thus graphically told: "Fortune, it might be said, ceased to be blind at the moment when to Oersted was allotted the privilege of first divining that it was not electricity in repose accumulated at the two poles of a charged battery, but electricity in movement along the conductors by which one of the poles is discharged into the other, which would exert an action on the magnetic needle. While thinking of this—it was during the animation of a lecture before the assembled pupils—Oersted announced to them what he was about to try. He took a magnetic needle, placed it near the electric battery, waited till the needle had arrived at a state of rest; then, seizing the conjunctive wire traversed by the current of the battery, he placed it above the magnetic needle, carefully avoiding any manner of collision. The needle was at once in motion. The question was solved. Oersted had crowned, by a great discovery, the labors of his whole precious life."

On July 21, 1820, the discovery was announced that a galvanic current passing through a wire placed horizontally above and parallel to an ordinary compass-needle, would cause that needle to sway on its axis to the east or west, according to the direction of the current through the wire. Oersted's discovery may be said to have pointed the way to the great applications of electricity to human use, for it showed that energy in the form of electricity could be converted into energy in the form of mechanical motion.

What are the Underlying Principles of the Galvanometer?—The

amount of deflection of a magnetic needle depends, to a certain extent, upon the strength of the cureent.[1]

"If the electric wire is above the needle, and the direction of the current is from north to south, the needle will tend to point eastwardly. Leaving the wire still above the needle, and changing the direction of the current so that now it flows from south to north, we find that the north end of the needle now deflects in a western direction. If the wire is changed to a position under the needle, it is found that all the motions are reversed; for passing a current from south to north the needle has an eastward inclination.

"It should be here explained that when we speak of the deflection of a needle the north end of the needle is uniformly the one referred to, the south end, of course, moving in an opposite direction.

"It can be readily understood why these movements should occur, and their reason. We have already indicated the cause of the natural inclination of the magnetized needle to place itself in a position pointing north and south to be the attraction of a much stronger magnet—the earth—and we may easily believe that an unseen force which causes the needle to point away from the north must also be of a magnetic character; and so it proves to be, and the reason of the deflection is as follows:—

"A wire carrying electricity becomes practically itself a magnet; that is, a straight current produces in a wire a magnetic field. This any one may easily prove for himself by passing an electric current through a wire of iron, copper, brass, or any other metal, and permitting the wire to dip into a heap of iron-filings. The filings will instantly cling to the wire and all around it, just as if it were a natural magnet. The electric wire having thus virtually been transformed into a magnet, when placed beside the magnetic needle, interferes with the attraction of the earth and pulls the magnetic needle to one side.

"The case is simply a very weak but very near magnet—*i.e.*, the current-carrying wire acting on a poised magnetic needle—in opposition to a very strong but very distant magnetic pole, the north pole of the earth; and thus the needle, being acted upon by both oppositely, takes up a half-way position,—as it were, 'on the fence.'

"The earth's magnetism tends to make the needle point north and south; the electric current acting on the needle tends to make it assume a position pointing east and west. The resultant force will, of course, be between the two, and will depend on their relative strength. If the current is very strong the needle will turn a long way around, but never farther than to a complete right angle."

Up to this point the effect of one parallel wire only had been considered. But if a greater deflection be required, and the battery power cannot conveniently be increased, what is to be done?

If the battery power cannot be increased in this manner, we can

[1] Electrical Measurements and the Galvanometer, T. D. Lockwood, 1890

increase its power of acting upon the needle by using a parallel wire on both sides of the needle; for, if the conducting wire is carried first over the needle from north to south and then back from south to north under the needle, the effect will be doubled. If the wire, instead of making only one such convolution round the needle, were to make two, the force would again be doubled; and if several combinations are wound around the needle, the force would be increased nearly in proportion to the number of convolutions.

If the convolutions are greatly multiplied so as to form a coil, the force is enormously increased, and we have what the first constructor of the galvanometer called a "*multiplier*." All galvanometers, therefore, consist of a coil of insulated wire and a magnetic needle delicately suspended in such a position as to be easily deflected by the passage of a current of electricity through the coil. These, with the addition of a dial-plate, graduated so that the movements of the needle may be interpreted, are the only absolute essential features of the instrument.

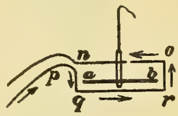


FIG. 17.

The galvanometer was one of the earliest results of Oersted's discovery; it was, indeed, in the same year (1820) that the first galvanometer was invented by Prof. Johann S. C. Schweiger, of Halle. He gave it the name of "multiplicator," the object of which, as aforesaid, was to multiply the electro-magnetic action of the current. This instrument is actually so sensitive that it serves to detect the weakest electric currents. All parts of the current traversing the elongated parallelogram, $p\ q\ r\ o\ n$ (Fig. 17), in the direction of the arrows, act in a similar manner upon the needle, $a\ b$, which rotates in a horizontal plane. If a be the south end and b the north end, the current will show a tendency at all points to turn the needle in such a manner that b shall project beyond the plan of the figure, while a will retreat behind it. The lower portion of the wire, therefore, supports the action of the upper in the same manner as does the current of the same force, moving in the same direction around the needle in the portions $p\ q$ and $r\ o$. A second current of the same force, moving in the same direction around the needle, will produce as great an effect as the first; so it will be with a third, a fourth, etc. A wire, therefore, wound around a needle in one hundred convolutions, all of which are traversed by the same current, must produce an action of one hundred times greater intensity than one of a single convolution; the current must not, however, be propagated later-

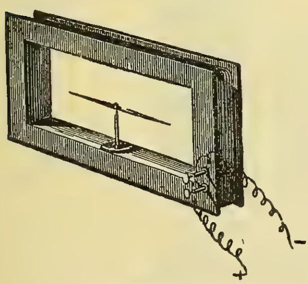


FIG. 18.—SCHWEIGER'S MULTIPLIER.

ally from one winding to the other, but must traverse the wire throughout its whole length, being carried actually around the needle.

The Schweiger multiplier is represented on preceding page. The difference between the rectangular and circular form is merely a matter of detail. Although the ordinary galvanometer, constructed as stated, is very well adapted to detect the presence or to indicate the direction of a current for some simple measurements, especially for those in which the deflection is not greater than fifteen or twenty degrees, it is not to be depended upon for any testing in which a greater deflection is produced, for the following reason, that when a needle is deflected it is not in the same position in its coil as when at zero; the greater the deflection, the farther is the needle removed from the position where its coil most powerfully influences it, and the nearer the needle approaches the right angle, at which point the coil has no influence on it at all, the weaker does the action of the current become.

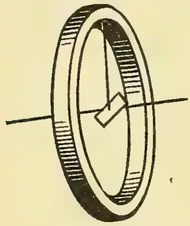


FIG. 19.

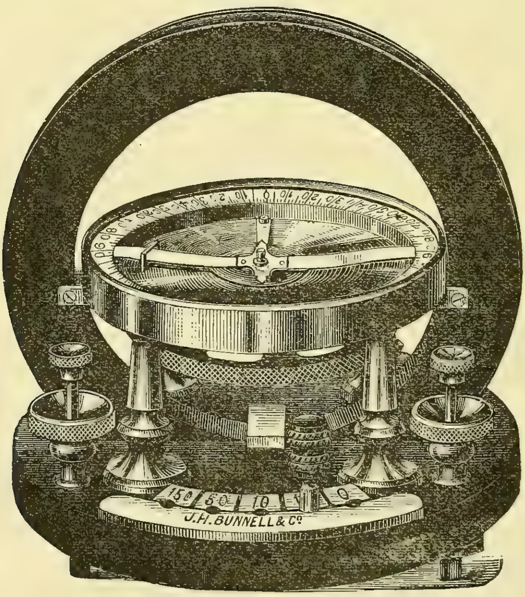


FIG. 20.—TANGENT GALVANOMETER.

In order to overcome this difficulty, and for other mathematical reasons, galvanometers have been invented in which the tangent, or line of the angle of deflection, is proportional to the strength of current measured. These are called *tangent*, or *sine*, galvanometers.

The Tangent Galvanometer.—The tangent galvanometer consists, broadly speaking, of a ring having a groove on its edge filled with in-

sulated wire, and provided with a needle, which must not be longer than one-sixth of the diameter of the ring, hung or pivoted precisely in its centre, as shown in Fig 19.

This instrument, as shown in Fig. 20, is mounted on a hard-rubber base, seven and three-eighths inches in diameter, provided with leveling screws and anchoring points. The galvanometer consists of a magnetized needle seven-eighths of an inch in length, suspended at the centre of a rubber ring, six inches in diameter, containing the coils. The coils are five in number, of the resistances 0, 1, 10, 50, and 150 ohms. The first is a stout copper band of inappreciable resistance; the others are of different-sized copper wires, carefully insulated. Five terminals are provided, the plug holes of which are marked, respectively, 0, 1, 10,

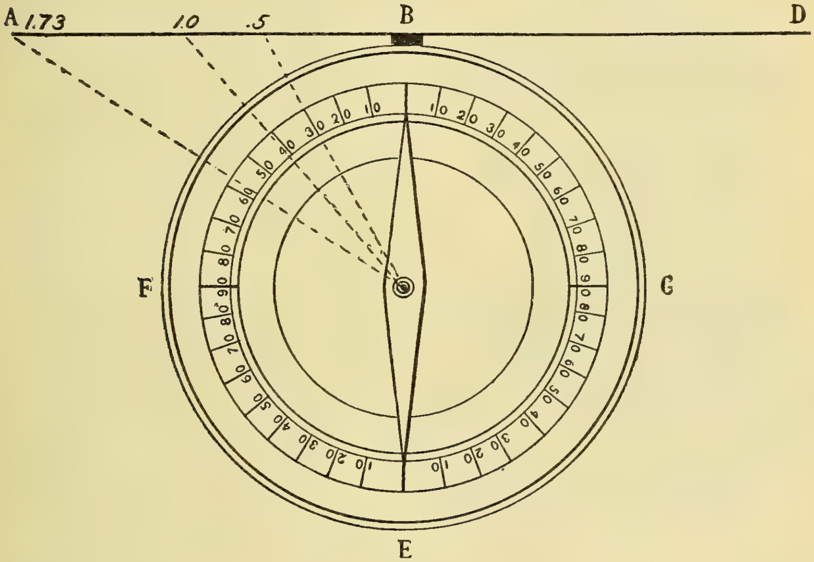


FIG. 21.

50, and 150. The ends of the coils are so arranged that the plug inserted at the terminal marked 150 puts in circuit all the coils at the terminal marked 50, except the 150-ohm coil; and so on, till at the zero terminal only the copper band is in circuit.

Fixed to the needle, which is balanced on jewel and point, is an aluminium pointer at right angles, extending across a five-inch dial immediately beneath. On one side the dial is divided into degrees; on the other it is graduated, the figures of the scale corresponding to the tangent of the angles of deflection.

For the benefit of the non-mathematical experimenter we may explain that a tangent is a line drawn at right angles to one of the diameters of any circle and touching the circumference, as in Fig. 21. *A* to *D* is a tangent to the circle *B*, *C*, *E*, and *F*.

In the case of the tangent galvanometer the dial of the instrument is the given circle, and the zero point is the point at which the tangent touches the circle. The tangent is therefore an imaginary line, which must be parallel to that diameter which connects the degree of 90 on one side to the same degree on the other side, and at right angles to the diameter or line connecting the two zero points. Let us suppose that the circle is the dial of a galvanometer marked off into degrees, and that the needle, by a given current, is deflected to 27 degrees; double the strength will not double the deflection, making 54 degrees, but will produce a deflection which, carried out, will show double the distance measured on the tangent scale, and that deflection will be 45 degrees. In mathematical tables the tangent of 45 degrees is 1. Therefore, that of 27 degrees is 5, or thereabouts; 64 degrees, 3; and 76 degrees, 4; all the intermediate degrees, of course, producing proportional fractions on the tangent scale.

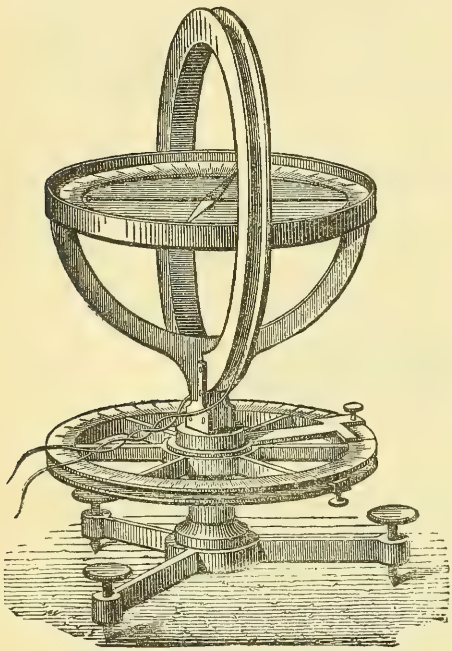


FIG. 22.—SINE GALVANOMETER.

Thus, we see that a current producing a deflection of 76 degrees on a tangent galvanometer is just four times as strong as a current producing a deflection of 45 degrees on the same galvanometer. If a tangent galvanometer is graduated to degrees only when it is used to obtain correct results, we must reduce the degrees to tangents by means of a table of tangents.

A tangent and sine table can be found in many of the first-class works,—as in Lockwood's "Electric Measurement."

The Sine Galvanometer.—The sine galvanometer, which was invented by Pauillet, is one in which the coils are made movable, so as to be capable of revolving on the axis around which the needle turns. The needle is pivoted, or suspended horizontally. A scale graduated with degrees is attached to the coils, and a pointer fixed in the base so that the angle through which the coils are turned can be observed.

When the needle is deflected by a current passing through the coils the coils are turned by hand, following the needle in its deflection; as the coils are thus turned they, of course, maintain their power on the needle, and it accordingly diverges still more, but the angle it makes

with the coils becomes less and less, until at length a point is attained at which the needle remains parallel with the coils. When this point is reached, the influence of the earth's magnetism exactly balances the deflective force of the current. The strength of the current that produces the deflection will then be directly proportional to the sine angle through which the coils are turned. It is customary, as in the use of the tangent galvanometer, to read off the degree, and refer to a table of sines for the required sine.

The sine galvanometer is not so convenient for general use as the tangent galvanometer is, being most applicable to scientific experiments and for measuring and comparing weak currents.

The astatic galvanometer is one of the most sensitive instruments employed; so is the Thompson mirror galvanometer.

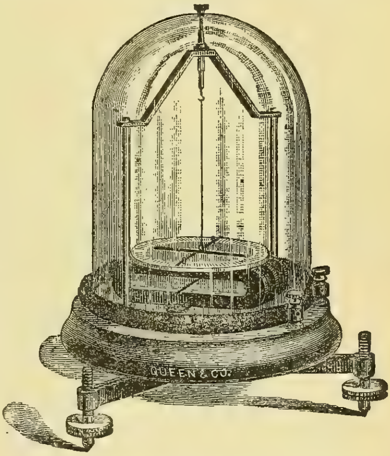


FIG. 23.—ASTATIC GALVANOMETER.

The differential galvanometer is one which has a needle poised or suspended like that of the tangent or sine galvanometers, but, unlike them, the needle is acted upon by two coils of equal length and resistance, insulated from one another with great care. These coils each surround the needle with an equal number of convolutions, which, in each wire, are equidistant from it.

When this galvanometer is used, one end of each coil with a wire leading to the pole of the battery is attached in such a way that the current flows in opposite directions through the two wires. Now, if the current in both coils is of the same strength, one tends to deflect the needle to the right and the other to the left, and the needle, being pulled with equal force in both directions, remains at rest. If, however, one current be made stronger than the other, the balance will be destroyed and the needle can be moved by the stronger current.

Unknown resistance can be measured with this galvanometer. This can be done in the following manner: We insert the resistance to be measured in the circuit of one of the coils. This, of course, weakens the current in that coil, and consequently its effect on the needle, which no longer remains balanced, but deflects to one side. If we now insert a rheostat in the other side and unplug the resistance until the needle again balances or comes to zero, we know that the current in each coil must again be equal, and, therefore, that the unknown resistance in the circuit of one coil must be exactly equal to the resistance unplugged from the rheostat.

A Dead-Beat Galvanometer.—So called on account of the readiness with which this galvanometer needle comes to rest, instead of swinging repeatedly to and fro.

There exists, besides these galvanometers for the commercial measurements of currents, a variety of forms. They are generally so constructed as to read off the ampères, volts, ohms, watts, etc., directly. They are called ampèremeters, wattmeters, etc. For their fuller description reference should be had to standard works on electrical measurements.

Having so far spoken of the cursory account of the theory of the galvanometer, and having described several of them, I will turn your attention to several galvanometers which possess certain features that, from the nature of the work they are called upon to do, are common to all galvanometers for medical purposes. We find the most important point connected therewith is, perhaps, the method of graduation. They are invariably of the fixed-coil, or "tangent" type,—that is to say, according to Steavenson and Jones ("Medical Electricity"), "the current indicated by any reading is proportional not to the angle of deflection, but to the trigonometrical tangent of that angle. Hence, it is necessary that the circle on which the position of the needle of the galvanometer is read must be graduated not uniformly, but so that the readings are angles whose tangents increase uniformly."

Calibration of a galvanometer is often called the graduation of a galvanometer. The galvanometer is graduated by dividing its circle into 360 degrees before the process begins.

The calibration of a galvanometer, for example, consists in the determination of the law which governs its different deflections and by which is obtained in ampères either the absolute or the relative currents required to produce such deflections. For various methods of calibration, see standard works on electrical testing, etc.

When a galvanometer is calibrated to read in milliampères it is called a "milliampèremeter," just as one calibrated to read in ampères is called an ammeter. The milliampèremeter is chosen as the standard for use in electro-therapeutics.

Many galvanometers are provided with a set of two or three resistance coils, which may be inserted in parallel with the galvanometer coils; they are usually of such values that they only allow one-tenth or one-hundredth or one-thousandth of the whole current to pass through the galvanometer.

The sensibility of a galvanometer may be varied in a very simple manner by the use of such coil, which is termed a *shunt*.[1] A shunt is a resistance coil, or coil of fine wire used to direct some definite portion of a current, taking it past a galvanometer instead of through its coils.

[1] Electricity and Magnetism. Fleeming Jenkin, F.R.S.S., L. and E., London. For the mathematical part relating to shunts, see works on physics.

Thus, let *G*, Fig. 24, represent the shunt. Let the resistance of the shunt be one-ninth that of the galvanometer, then of a total current from *C* to *D* nine parts go through the shunt and do not deflect the needle, while one part goes through the galvanometer; only one-tenth of the whole current is, therefore, effective in deflecting the needle, and the deflection, supposing a mirror galvanometer be used, is only one-tenth of what it would have been had no shunt been used. Similarly, by making the shunt equal in resistance to one-ninety-ninth of the galvanometric

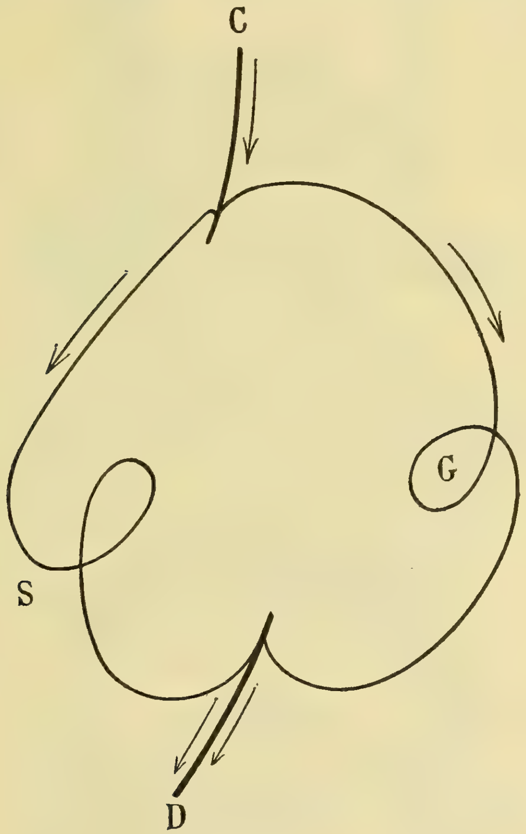


FIG. 24.

coil, we reduce the sensibility of the instrument to the one-one-hundredth part of its original sensibility.

All instruments used by electro-therapists are invariably calibrated and marked, as aforesaid, to read in milliampères, by all their manufacturers. These milliampèremeters are made up into two different styles, as the vertical and horizontal. Fig. 25 is a horizontal one designed for physicians; it is direct reading, and thus a means of obtaining quick, accurate, and reliable electrical measurements, such as

have hitherto been unattainable. No time is required for adjusting or waiting for the needle to come to rest, but readings can be taken immediately as soon as the circuit is closed. This instrument is accurately

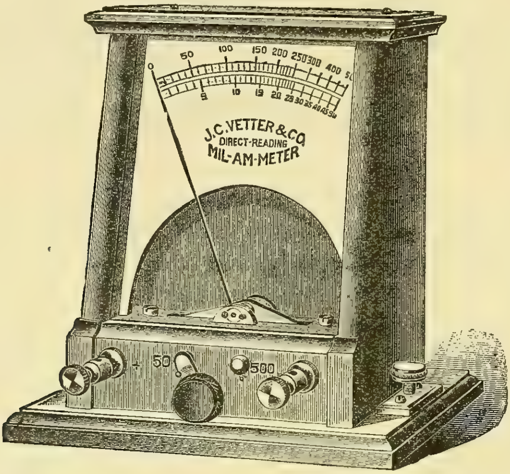


FIG. 25.—HORIZONTAL MIL-AM-METER.

calibrated and standardized. The staff is of hardened steel pivoted in ruby bearings with jeweled end-pieces ; it is provided with a switch, which, when placed on the 50 button, selects the lower or red scale on dial read-

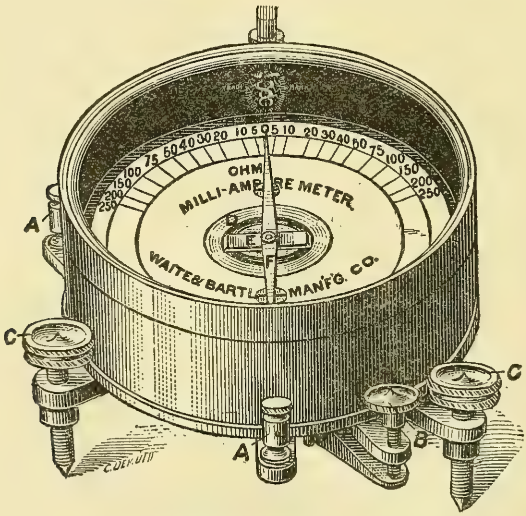


FIG. 26.—VERTICAL MILLIAMPÈREMETER.

ing from 0 to 50 milliampères, and when placed on 500 reads black or top scale, 0 to 500. It is mounted in a well-made mahogany or antique-oak case. For more delicate measurement this milliampèremeter is divided

on a lower scale, from 0 to 10 milliampères, and again subdivided in such a manner that one-tenth of a milliampère can readily be read off.

Among the vertical milliampèremeters the one made by Waite & Bartlett is the best, for many reasons.

The coils are made of two semicircles, so that practically you have a horseshoe solenoid for affecting the needle. The resistance of these coils combined averages fifteen-hundredths of an ohm. The magnet is made in horseshoe form, the poles of which swing in a circular groove in a copper block; the effect of this is to dampen the magnet, and so make it dead-beat. The magnet is supported on a jewel-point, which is so arranged that it can be lifted from the needle-point while being transported, which prevents injury to point of needle and jewel. All of the milliampèremeters made by the Waite & Bartlett Manufacturing Company are calibrated individually, and, for this reason, are uniform and

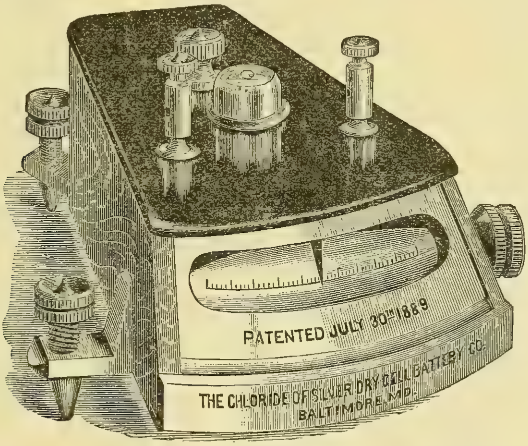


FIG. 27.—MIL-AM-METER.

correct. The instruments are in an all-brass case, finished in the same style as a microscope.

Another very excellent vertical mil-am meter is the one manufactured by the Chloride-of-Silver Dry-Cell Battery Company, of Baltimore. These meters have qualities which must also prove themselves satisfactory to the therapist. The following claims are made for them :—

1. An absolute electrical meter should be *accurate.* The best conditions for this accuracy are the use of short magnetic needles in connection with a long pointer. In this meter the magnetic needles are less than one inch long, while the pointer—made of aluminium for lightness—is four inches long, thus securing an extended indication on the scale for a very slight movement of the needles.

2. Such a meter should be as free as possible from variations due to changes of time and surroundings. This double object is accomplished

by employing a horizontal movement and an astatic system of magnetic needles, controlled by a fixed magnet, which is permanently under the influence of an armature or keeper, for preserving a uniform degree of magnetism. Such a system of needles is free from the influence of the earth's magnetism, and is the most constant in its action.

3. Friction must be entirely absent. This is accomplished by the use of a perfectly-pointed steel pivot working in a concave jewel, as in the best absolute galvanometers known to electricity.

4. The free parts of the instrument must be provided against accidental displacement. This is attained by a simple detail of mechanism, so that the magnetic needles cannot get off the pivot, even if shaken wrong-side-up or otherwise roughly used. A simple-locking device also provides for lifting the needles from the pivot and holding them fixed for transportation.

5. A physician's milliampèremeter should be readable from either a sitting or standing position. In this meter the face is at the front, at an angle which satisfactorily meets these points.

6. The perfect meter should have a wide range of measurement. This has been obtained in this meter by an entirely new arrangement. Three independent reading-scales are stamped at equal distances apart on the three faces of a celluloid roller. One of these scales is marked in 5 milliampères, divided into halves. The second scale is divided into 25 milliampères, and the third scale reads up to 250 milliampères. This meter reads directly.

Besides these described there are others, as the Weston standard direct-reading mil-am-meter, which has a scale of 0 to 500, 0 to 10. The instrument is readable from 0 to 10 milliampères by one-tenth; 0 to 500 by 5 milliampères. This instrument will operate in any position, and is not influenced by magnetism.

The McIntosh milliampèremeter has many advocates, and is certainly a very fine and accurate instrument. The D'Arsonval and the Gaiffe are also well known, besides many other American and foreign makes.

The Galvanometer Battery Gauge.—This is a new instrument entirely, and differs essentially in its construction and aim from all other galvanometers. This gauge is constructed and calibrated to furnish a reliable standard for the practical measurements of current-strength of from 1 to 5 cells of ordinary batteries. A good Leclanché cell will indicate about 9 degrees; Burnley dry battery, 14 degrees; Lockwood American District (blue vitriol), 6 degrees; Crowfoot Western Union form, 8 degrees.

These gauges, being calibrated to a single standard, furnish an accurate instrument for battery comparisons or condition tests. The gauge being a true galvanometer, without springs or magnetic devices, its indication for a given force is always the same. It can be used standing upright on table or desk, or suspended by its chain and ring,

which brings the needle to zero when no current is passing the instrument. Also, on account of their normal positions being upright, these gauges can be advantageously used as permanent circuit-indicators. The action of the needle is "dead-beat." It moves to and remains, without oscillation, at whatever indication the current calls for.

Two silk-covered conducting cords are attached to each gauge. These cords are provided with new and improved tips, made so as to enter any binding-post, and to be held by the binding-screw in the usual way, or, being square, can be firmly held by the English form of binding-post. These tips have a spring-clamp, by which they can firmly grip

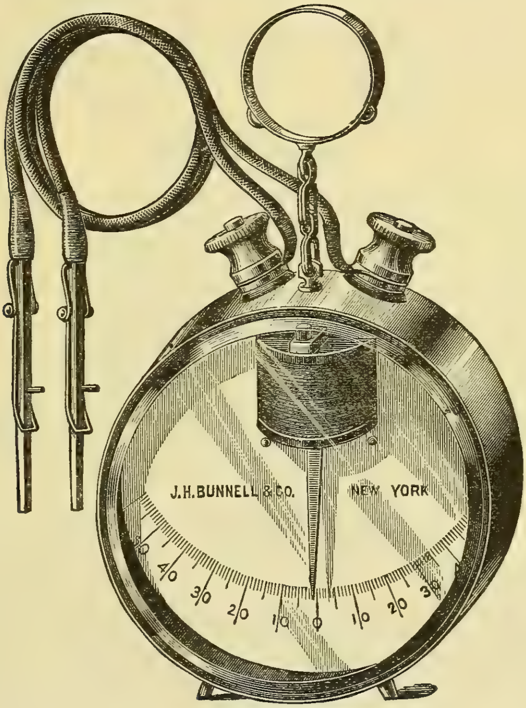


FIG. 28.—THE GALVANOMETER BATTERY POCKET-GAUGE.

naked wire (up to No. 16) at any exposed point, and thus also be able to detect a flow in circuits of fire-alarms, burglar-alarms, etc. Such a gauge must become serviceable to medical men to detect the power of their batteries, which is highly essential during or before treatment of any case.

RHEOSTATS.

The name rheostat was originally given by Wheatstone to an instrument which he devised for the purpose of varying at will the amount of resistance in a circuit.

The modern rheostat is a box containing a number of spools filled

with insulated wire; the resistance of the wire on each spool being equal to some multiple or submultiple of the ohm, the unit of resistance. The several coils (Fig. 29) and a complete box-rheostat (Fig. 30) are shown below.

The different coils may be of any required resistance, and may be

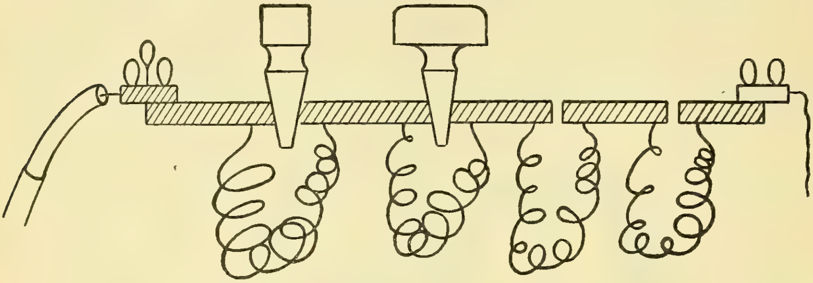


FIG. 29.—COILS.

varied indefinitely. They are usually made to increase consecutively, as, for example, 1, 2, 5, 10, 20, 50, 100, 500 ohms, and so on.

If all the plugs are in their places, there is practically no resistance between the terminal binding-screws; but if any of the plugs be taken out, the coil of that section is brought into the circuit. It follows, then, that by withdrawing any or all of the plugs we can introduce less or more resistance.

Numbers representing the various resistances of the coils are usually

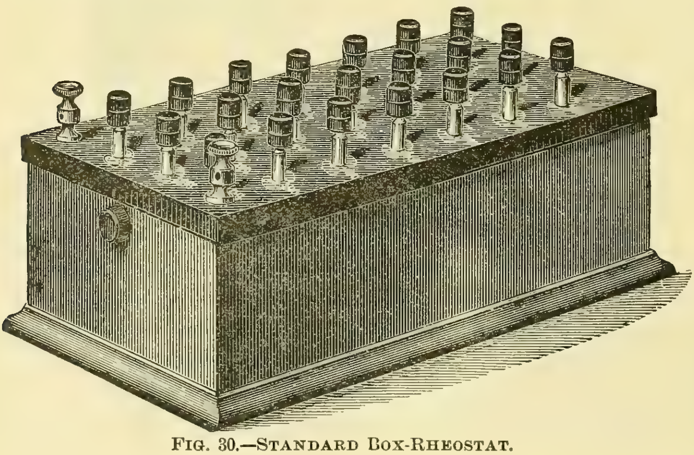


FIG. 30.—STANDARD BOX-RHEOSTAT.

placed opposite the holes, and by adding together the numbers unplugged we ascertain the total resistance inserted.

The wire used in resistance coils is generally made of German silver, because the resistance of that alloy changes very little with variations of temperature; it is insulated with silk, and always wound double, as

shown, so as to neutralize any inductive action of the convolutions on each other, and also to prevent the coils from affecting galvanometers near them ; when so arranged, the current flows at the same time in two opposite directions round the spool, effectually preventing any inductive troubles.

It is usual to so arrange the different resistances that, by properly combining them, any value, from a fraction of an ohm to 10,000 ohms, can be obtained.

Those rheostats which are now mostly used by medical men are of the wire, the water, and the carbon order. I will describe and illustrate the three different kinds. They all have their merit and their demerit.

The Vetter Carbon Rheostat.—The principle adopted in the construction of this rheostat is the effect of variation in resistance, which

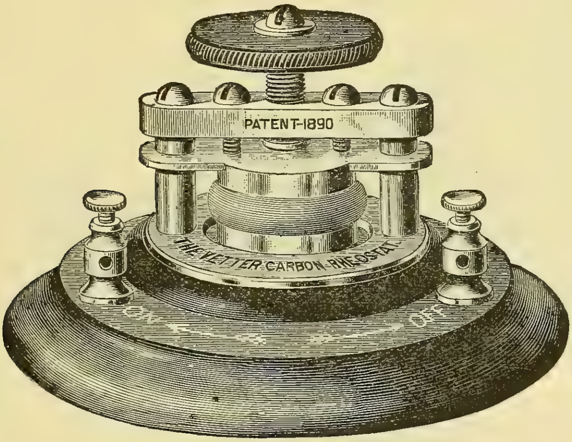


FIG. 31.

takes place in carbon with a change in pressure. A quantity of specially-prepared carbon, in a finely-divided state, is placed in a small rubber pouch or cylinder, which is inclosed by two metal plates, to which the two sides of the circuit are connected. The lower plate is fixed to the base of the instrument, and the other, traveling in upright guides, can be depressed, by means of a screw with a fine thread, so as to compress the carbon in the rubber-cylinder. In this way the current passing can be adjusted with the greatest nicety. The variation in the resistance of the rheostat follows the movements of the screw through very wide limits, thus controlling from off or no current to the full capacity of the battery.

This instrument is far in advance of any rheostat, switch-board, or cell-selector. It imposes equal work upon all the cells of a battery, maintaining the current throughout the series of uniform and equal strength. There is also a saving of a mass of complicated wires from the cells, as only the two terminal wires from the battery are necessary.

The absence of liquid in glass and the many advantageous features it possesses make it the most desirable instrument for the purpose.

The Water Rheostat.—This is another resistance apparatus much lauded over by some medical men. There are several of them in the market. The latest of them is the Bailey current-controller.

This instrument, briefly described, consists of two triangular-shaped carbon plates, each carrying a conical sponge at one of its angles, and mounted over a glass vessel containing water. By means of a worm gear operated by a thumb-knob the sponge-tips are gradually immersed into the water and toward each other. It is so arranged that by turning a thumb-screw the left-hand plate may be unlocked from the gear and immersed as far into the water as desired, and then the other plate gradually moved toward it. This, the last method, gives a more gradual increase of current, as one plate is moved in place of the two. Each plate

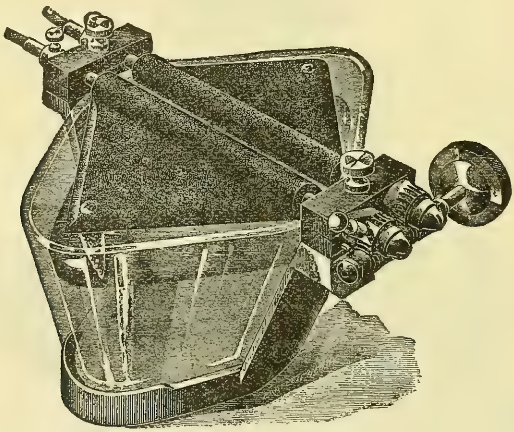


FIG. 32.—BAILEY CURRENT-CONTROLLER.

measures three and one-half inches by three and one-half inches by four inches; the entire device is over all seven inches long, seven inches wide, four and one-half inches high, and weighs two pounds. This current-controller, or rheostat, will give a current at the outset more feeble than any other instrument of this kind or character, and will increase the current without variation or fluctuation. When the plates are raised out of the water they are separated fully three-sixteenths of an inch; thus it is impossible for the escape of the current by means of water adhering between the plates, or by moisture or condensation.

The principal advantages of the water rheostat over the wire-coil rheostat, are as follow: Its simplicity, avoiding the complicated wiring incidental to wire rheostats; greatest certainty of preventing shocks, and its low value.

The ordinary water rheostat is known to most practitioners. It consists of a glass cylinder, water-tight, and filled with water or some

saline solution. It terminates below in a metal foot and binding-screw, and a metallic rod, moving stiffly, passes in from above through a collar, and this carries the other binding-screw. When the rod is pushed quite down it touches the base of the tube, and the circuit is completed through the metallic contact; when it is raised the current must pass through the badly-conducting fluid.

A good rheostat is the McIntosh hydro-platinum. The figured one in the cut is devised for the special object of rendering it possible of increasing or decreasing the strength of the current in absolute gradual gradations, from zero to the full current-strength and back again.

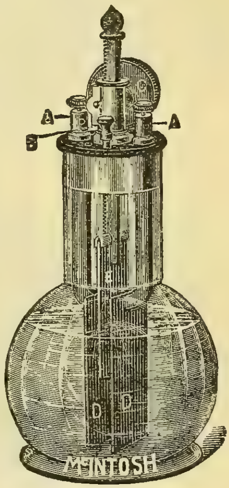


FIG. 33.

Between two small, thin sheets of platinum (*D D*) suspended in water with suitable attachments (*A A*) for one pole of the battery is suspended a third piece of platinum (*E*) with pointed end, which can be lowered or elevated gradually in the water between the other two sheets (*D D*), by means of a delicate ratchet combination (*B C*) above. This plate is connected with the other pole of the battery by one of the binding-posts (*A*). When plate *E* is elevated so that its pointed lower end is out of the water no current can pass the instrument, but as it is gradually lowered into the water the resistance becomes gradually less and less, until the desired current-strength is reached, or until the full capacity of the battery is obtained. Thus, by elevating or lowering this central sheet, a current of great strength can be perfectly controlled in gradual gradations, no shock being possible.

There are other kinds of rheostats made by the various surgical-instrument makers throughout most of our large cities. Those made by the Waite & Bartlett Manufacturig Company are perhaps the most widely known.[1] The Massey current-controller is a modification of the one known as the old Butler rheostat. The above-named firm have undertaken its modification, and to-day it looks as follows: The disc is made of slate with the cone-shaped surface roughened for retaining the graphite coating. The advantage of the slate is that it does not become soiled like the marble, and it always presents a neat appearance. The brush for moving over the resistance surface is made of spring-brass nickel plated, sufficiently broad to span the broadest part of the leaden portion, and the spring is split up in several places to insure perfect contact over the entire surface upon which it rests. One of the binding-posts attached to the wooden frame surrounding the disc connects with

[1] Augustin H. Goelet, M.D.: The Electro-Therapeutics of Gynæcology, vol. i, pp. 135, 136, 137.

the base of the leaded surface by means of the spring contact under the cap, and the other with the central pivot, to which the brush is attached by a lever; so that there is a break, so to speak, between the two when the brush stands at the point marked "start," removed from the coated surface. As the brush is moved upon the graphite the resistance is diminished the nearer it approaches the base. The graphite, which is really a good conductor of the current when spread out over a flat surface like this, offers a considerable resistance. In order to increase the resistance at the start, so as to permit the current to be turned on gradually from a battery of a great number of cells, it is necessary to make the graphite coating very much thinner there than elsewhere, and if too much has been put on it should be rubbed off until its presence is

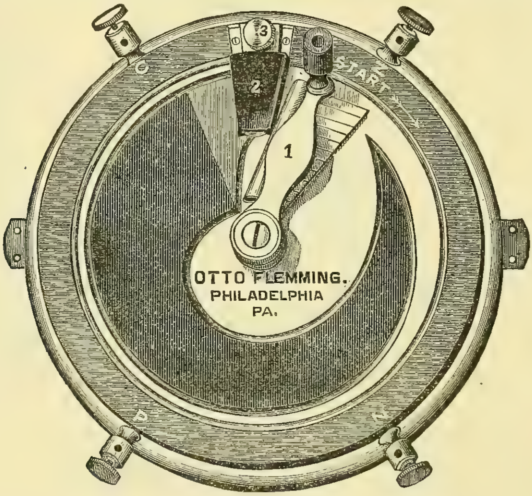


FIG. 34.—THE MASSEY CURRENT-CONTROLLER.

scarcely perceptible at and near the starting-point. The only objectionable feature about the instrument is the perishable character of the graphite coating, which is being constantly rubbed off by the brush, but it is easily renewed by rubbing over the surface a carpenter's lead-pencil, or, in fact, an ordinary pencil; but the former having a larger surface of lead, the coating can be renewed more rapidly. It is possible with this rheostat to gradually remove the entire resistance by moving the brush up over the surface which has been covered with graphite, or, at least, the remaining resistance is so little as to be inappreciable.

The advantages of this rheostat are that it is flat, it occupies a very little space, it cannot be upset, and the connections are practically indestructible. It can be readily removed from the cabinet or table and transported for use elsewhere, though its size (the diameter being about seven or eight inches) makes it rather an awkward instrument for carrying conveniently in a bag.

Dr. A. H. Goelet, recognizing the fact that a smaller rheostat was needed for use with a portable battery at a patient's house,—one small enough to make a convenient package and readily carried in the pocket

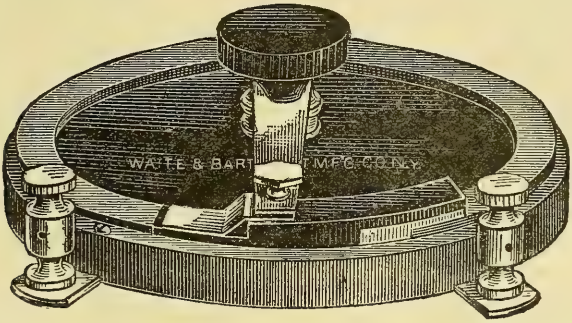


FIG. 35.—GOELET'S SLATE POCKET-RHEOSTAT FOR GALVANIC CURRENT.

from place to place,—was led to suggest the modification of this rheostat shown in the cut (Fig. 35), which is made for him by the Waite & Bartlett Manufacturing Company. It is a small disc of slate, only three inches in diameter, marbleized on the upper face and around the

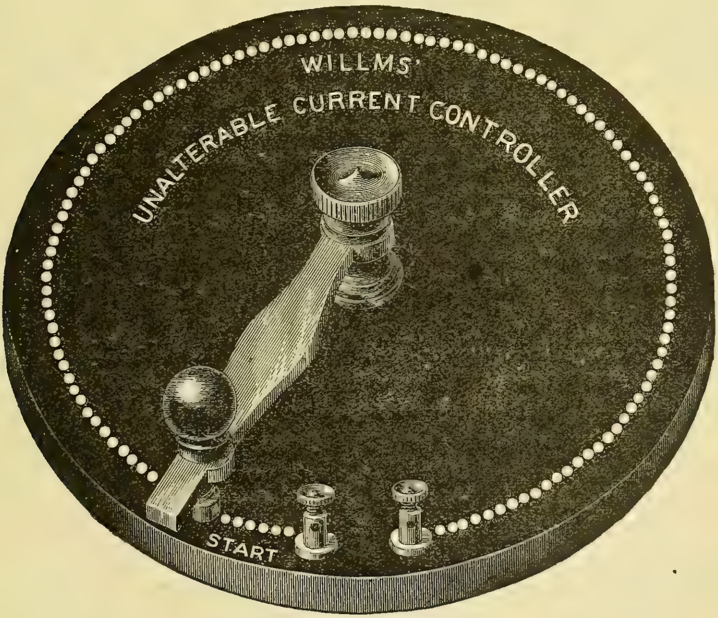


FIG. 36.—WILLMS'S RHEOSTAT.

side. Around the margin of the upper face is a raised surface about one-quarter of an inch wide, not marbleized, but roughened for receiving a coating of graphite. The connections are made in the same

manner as in the Massey instrument. The contact of the lever with the graphite surface is made by a small wheel ground to fit the raised surface, which is made level, and in front of the wheel is placed a projecting spring-pressure foot, like that on a sewing-machine, to which is attached a piece of graphite for constantly renewing the coating. The object of the wheel is to make it move more smoothly and to avoid sudden jerks. The lever is turned by a thumb-screw fixed to the pivot passing through the centre of the disc, and can be manipulated with greater ease than the other instrument. It can be used with forty or fifty cells as satisfactorily as the other instrument, but the same care must be observed not to have the graphite coating too heavy at the starting-point. Nearly all the resistance is cut out at the finish. A larger size is made, but it is not so convenient.

Fig. 36 represents a rheostat, recently introduced by the Chloride-of-Silver Dry-Cell Battery Company, of Baltimore, designed by Mr. Charles Willms, of the firm. The resisting material, consisting of common glue, graphite, and metal-filings (brass preferred), is placed on the under surface of the top plate; the graphite being really the resisting material, the brass-filings collecting the current and conducting it to the metal contact-points leading to the surface, where the turning-crank forms a connection with them. This is considered a very finely-constructed and practical instrument. Most of the portable batteries have been so designed that a rheostat is placed on the mechanism in such a way that is most practical.

Introductory Remarks on Primary Batteries.

Battery Defined.—An electric battery, or cell, as a single element is called, is a device for the conversion of the potential energy of chemical separation into the energy of an electric current. Thus, the metal (zinc) and the sulphuric acid which acts chemically on it represent energy of chemical separation in the potential form. If now the zinc is placed alone in the acid, this energy of chemical separation is converted simply into heat, when the zinc displaces the hydrogen of the acid with the formation of zinc sulphate; but if the displacement of hydrogen by zinc is made to take place under certain less-simple conditions, then a part at least of the kinetic energy developed takes the form of the energy of an electric current. The arrangement of parts necessary to secure these conditions, which determine that the transformed energy shall be electrical, is called a battery, or voltaic cell.

The term "battery" is now to be found substituted in all works on electro-physics for the former historical one, "pile." It is stated by many that the word "pile" is, however, more correct.

The invention of the "electric pile," or battery, was Volta's great contribution to science, and dates from the year 1800. For many years it afforded the only means of generating electricity in considerable and

manageable quantities. Through its use many of the most remarkable discoveries were made. In various forms its practical applications have become so extensive and so common that it is probably the best known of electrical instruments. Its invention evidently came to Volta through his reflections upon the contact theory. Believing that electrical separation takes place when two dissimilar metals come in contact, he thought to magnify the effect of a single pair by increasing the number. Pairs of dissimilar metals of like dimensions were bound together by placing a thin, moist substance between consecutive pairs. Discs of metal, consisting of silver coins and pieces of zinc, and moistened paper, were used, and, when put together, the pile was formed as shown in the figure. When this was done, he found it no longer necessary to use so sensitive an electroscope as the legs of a frog to detect the electrification. He could himself feel the shock it produced by touching the opposite extremities of the pile, and immediately convinced himself of the identity of electricity with the so-called galvanism. All of the characteristic effects of electricity, as produced by friction upon glass, sulphur, and other substances, could be shown by the new instrument. It is interesting to note how nearly an Englishman—Professor Robinson—came to hitting upon the same invention. Volta modified the form of his apparatus by placing the two dissimilar metals in cups of water, and then joining them together by metallic conductors, thus putting his battery into a shape which it has retained, practically, to the present day.

FIG. 37.—COMPLETE PILE.

The pile shown in Fig. 37 exhibits the appearance of the instrument called the column-pile, which has to-day but an historical interest. It is a pile of discs, and the figure here represented is a *fac-simile* of the first cut published of the battery.[1]

First Idea of the Pile, or Battery.—If you immerse a thin plate of commercial zinc into diluted sulphuric acid a very lively action takes place; the zinc dissolves, and a considerable quantity of hydrogen is given off. It is, indeed, this process which is generally employed in the preparation of hydrogen-gas. But if, instead of ordinary zinc, pure zinc is used, the action takes place very slowly, and the bubbles of hydrogen remain attached to the plate of zinc and protect it from further action of the acid. If a wire or thin plate of platinum be now placed on the same, as soon as the two metals touch at one point the action becomes extremely energetic; the zinc dissolves and hydrogen is given off, but from the platinum, and no longer from the zinc.

As soon as the contact of the two metals ceases, all action upon the zinc and all giving off of hydrogen are suspended. This important experiment is to be credited to De la Rive. It throws much light upon all

[1] In my historical sketch I have described the origin of the voltaic cell, etc.

that follows. It is equally successful when you substitute for the platinum silver, copper, or even iron, and gives the same result when the metals have their points of contact either *in* the liquid or *out* of it.

De la Rive's experiment shows that if two metals were to have their point of contact *not in* the liquid, but *out* of it, as Fig. 38 represents, the chemical action still takes place in the liquid, as stated above. It also takes place if, instead of bringing the two plates of metal into direct contact, you put one upon the upper part of the tongue and the other upon the under part, when you will experience a slight sensation, like that of a feeble electric shock, and a peculiar taste will also be noticeable.

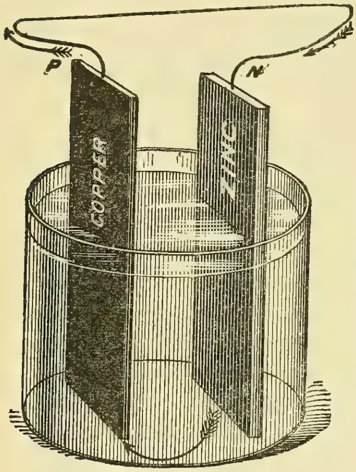


FIG. 38.

If you place upon the dry part of the zinc a strip of paper dipped in iodide of potassium, and then touch this dampened paper with the platinum, a blue spot is immediately produced, which shows that the iodide has been decomposed and the iodine set free. These experiments can also be made if you attach to the zinc and platinum two wires, and operate with the two loose ends. If you place one of these in the neighborhood of a freely-suspended magnetic needle, you will notice that the needle will deviate slightly from its north-south direction as soon as the contact is established between the two loose ends of the wires.

FIG. 39.

These observations prove that a singular phenomenon is established by the co-operation of the two wires, which is the cause of various actions,—physiological (upon the tongue), chemical (upon the iodide of potassium), magnetic (upon the needle).

The two metal plates immersed in the liquid are called *electrodes*, and the wires, long or short, which are attached to the electrodes, and which permit the transference to a distance of the effects produced by the battery, are called *rheophores*. The *rheophores* are generally short, and often end in a longer wire, to which the name of *conductor* is given.

The term "circuit" of the current is applied to the whole, formed by

the battery, the rheophores, and the solid or liquid conductor through which the current passes. Every apparatus which produces a current is a battery.

It is said that the circuit is *open* when at any point whatever the conductor be disconnected, as then all the effects of the current cease and the *current does not circulate.* The current is *closed* when the two parts of the conductor, which were separated, are brought into contact with each other and the current commences to flow.

It is said that a battery is in *short circuit* when the conductor connecting its poles has a null resistance; that is, when it is very short. It has thus come to be said that, *in the conductor, the current flows from the positive pole of the battery* (+plate of copper) to the negative pole (—plate of zinc); a transference of a peculiar fluid from one to the other of these points being thus implicitly admitted. Let us say, in passing, that this way of looking at things, after having been abandoned in science, shows a tendency toward re-acceptance, with a few changes; so that the conventional language, which had not been changed, finds itself again in accordance with the theoretical ideas admitted.

The cell formed of the electrodes of zinc and copper, immersed in sulphuric acid, is more particularly known under the name of volta. By changing the nature of the liquid and the electrodes, an indefinite number of cells which produce the same kind of energy can be obtained.

Chemical Reaction in the Simple Voltaic Cell.—If we suppose that the arrangement of metals and acid in the cell is as follows:—

Zn	|	H_2SO_4	|	H_2SO_4	|	Cu
Zinc.		Sulphuric acid.		Sulphuric acid.		Copper.

then the operation, which repeats itself over and over when the two metals are electrically connected, may be represented thus:—

$$\underbrace{Zn \quad | \quad H_2SO_4} \quad | \quad \underbrace{H_2SO_4 \quad | \quad Cu}$$

$$\longrightarrow$$

giving $Zn\,SO_4$	|	H_2SO_4	|	H_2	|	Cu
Zinc sulphate.		Sulphuric acid.		Hydrogen.		Copper.

The arrow represents the direction of the current through the cell. The zinc and hydrogen are both placed in the direction of the current, while the so-called "sulphion," or SO_4 part of the acid, is displaced in the other direction. All metals and hydrogen are electro-positive, and travel in an electrolyte with the positive current. Zinc sulphate is formed at the expense of zinc and sulphuric acid, and hydrogen-gas is set free at the copper plate. The simple chemical action taking place is the displacement of the hydrogen of the acid by zinc, forming zinc sulphate in place of hydrogen sulphate.

Inconstancy of the Simple Voltaic Cell.—It is found that all cells formed of two electrodes immersed in a liquid present an immense drawback; namely, their action decreases very rapidly from the beginning of the action. There are two causes for this decrease, of which the following is an analysis:—

The first is the loss of acid from the dilution. It can be easily understood that water acidulated in the proportion of 1 to 100 will act less energetically than water acidulated in the proportion of 1 to 10. This cause of the weakening of the battery is not felt until the expiration of a certain time, and it is easily avoided by adding, from time to time, acid to the dilution.

The second is the deposit of hydrogen upon the copper. If the current be interrupted during a length of time sufficient for the freeing of the hydrogen, it will be seen, as soon as the current is again closed, that the intensity assumes its original vigor. It suffices, indeed, to agitate the plate of copper, in order to cause the gas to free itself and to give to the current its initial intensity.

Constant batteries are those in which this second cause of weakening, called *polarization of the electrode*, is removed. The presence of hydrogen upon the electrode opposes a double resistance to the passage of the current, *a passive resistance* and *an active resistance;* it is the latter which is properly called *polarization of the electrode.* To depolarize the electrode is to provide against these resistances by suppressing the freeing of hydrogen.

In understanding perfectly everything pertaining to this question, therein will be found lies the whole difficulty concerning the improvement and perfecting of batteries.[1]

Various reasons have combined to designate the *positive electrode* as that one which represents the negative pole of the cell (zinc in Volta's battery), and the *negative electrode* as that one which represents the positive pole. (Copper or platinum in the cells which have occupied us to the present.)

One of these reasons has already been indicated, which is that the current enters the liquid of the battery by the negative pole and goes out by the positive; in other words, the *positive electrode* is that by which the electricity enters the cell.

In order to avoid difficulty in the choice of these denominations, one may, in speaking of them, call them the positive pole and the negative pole, when desirous of designating the corresponding electrodes according to the custom of practical men. But, if one wish to employ absolutely correct and scientific terms, great care should be taken in the application of them, in order to avoid the confusion consequent upon an awkward attempt at precision in language. Daniells gives in his work, "Introduction to Chemical Philosophy," another denomination, which

[1] Elementary Treatise on Electric Batteries. Alfred Niaudet, France.

ought to be employed more frequently than it is, because it presents the expression of a *fact*, and does not depend upon theoretical ideas. He calls the *generating electrode* that one which plays a part in the chemical action; while it is the zinc in the cell which we have considered. He designates as the *conducting electrode* that one which is not attacked, but which serves, however, to complete the cell. He adds that the first may also be called soluble electrode.

Battery Cells Joined in Intensity.—I have described the most simple cell that can be prepared, composed of two electrodes of copper and zinc immersed in acidulated water. The cell of Volta's column-battery does not differ essentially from this one; it is composed of two discs, one of copper and the other of zinc, separated by a circular piece of cloth, saturated with acidulated water.

Volta discovered, by delicate means, that the force of the current increased as the number of cells was augmented, and one of the most brilliant discoveries of modern times was the result. He thus showed that it was possible to add one source of electricity to another and to still a third, in such a manner as to obtain a multiple source of an indefinitely increasing power.

The Voltaic Battery and its Offsprings.—The batteries known as the column, Volta's Couronne de Tasses, Cruikshank's, Wollaston's, Spiral, Munke's, and Sand's,—all these differ only in their arrangement from that of Volta's; in every one we find the zinc, the copper, and the water acidulated with sulphuric acid.

It will be found that the chemical action is the same in nearly all batteries: dissolving of one metal, freeing of another. In all forms of Volta's battery hydrogen-gas is given off and the zinc will be dissolved without closing the circuit; that is, without the production of electricity by the battery. This is one of the greatest faults of this battery. It is consumed without doing any useful work. In most batteries the same difficulty is presented, with, however, a few exceptions.

General Remarks upon Batteries.

Ideas upon Electric Resistance.—The most simple way of showing the passage of electric currents in a conducting body is to bring its force to bear upon the magnetic needle. For instance, let us suppose that the conductor of a galvanometer, or of a simple detector, be inserted in the circuit of the current of a battery, and that the deflection of the needle be 25 degrees. Now, if the circuit be lengthened by the addition of a wire, the deflection will be seen to diminish to 15 degrees; and if the circuit be made still longer, the deflection of the needle will not exceed 10 degrees. We may thus draw the following conclusions:—

1. The intensity of the current is less in the second instance than in the first, and less in the third than in the second.

2. The influence of the additional wire being only passive, the reduc-

tion of the intensity of the current is due not to the decrease of the generating force, but to the increase of the resistance.

These experiments give a practical idea of the *resistance* that conducting bodies offer to the passage of currents; and they also demonstrate that the resistance of a conductor increases with its length. Very exact and oft-repeated measurements have proved that the resistance of a conductor is in proportion to its length, and in an inverse proportion to its sectional area. These laws can be found in all works upon physics.

General Remarks on Electro-motive Force and Resistance.

In all machines in motion is seen a power or cause of movement, and there are also resistive forces which tend more or less to slacken this movement or to stop it altogether. For instance, to illustrate this by a windmill. The large arms, under the pressure of the wind, cause the millstones which crush the grain to turn. In the working of the mill we see, first, a power,—the wind,—which produces the movement; then there is a resistance offered by the grinding; this resistance moderates the pace of the arms, and if the wind falls it stops them entirely. At first sight there are two mechanical elements apparent: the power, or cause of movement, or motive force; and the resistance, or work. A careful examination will show, however, that the resistance is complex; and that offered by useful work, as the grinding, should be distinguished from that which is the result of the friction of the different parts of the machine in motion and of certain secondary phenomena. All practical men know that a badly-oiled rubbing surface is sufficient to slacken the movement of a machine, and even to stop it; all know the importance of friction in the different parts of the machine, and of the stiffness of the belts and ropes. These inevitable causes of the slackening, which absorb a part of the motive power at the cost of the useful work desired, are called *passive resistance*. Every one knows that these resistances should be diminished as much as possible, although they cannot be totally suppressed.

Attention is here called to the fact that in many cases no useful work is done, and that there then remain only passive resistances. If the miller take away his millstones and still permit the mill to turn, it is evident that there remain only those passive resistances (friction and others) which are produced by the machinery remaining in motion. If all the machines of a large factory be disconnected from the motion-giving steam-engine and the engine continue to turn, there will only be present the motive force furnished by the engine itself and the passive resistances existing in the engine, in the shafts, and in the different agents of the transference of the movement which still remain in motion. If now the steam-engine run entirely alone, not being connected with any shaft or any piece of machinery outside of itself, we have not only the example of a system in which there are force and passive resistance, but also that

particular instance where these passive resistances are inherent to the force-giving machine and inseparable from the production of that force.

In a circuit through which an electric current flows the same influences are to be found; first, a force residing in the battery and called *electro-motive force;* next, the work; and, finally, the passive resistance. The work may be found in the movement of the clapper-spring of an electric bell; it may be in the movement of a telegraph instrument placed at a great distance from the battery; it may be in the movement of an electro-motor or an electro-magnetic machine which lifts a weight; it may be in a chemical decomposition, produced by the passage of a current in the production of heat, and consequently of light, in a voltaic arc, etc.

Passive resistances are the results of the circulation of the current in the different parts of the circuit. We have explained how their existence may be ascertained, and we have designated them by this one word, *resistance.* If the current produce no real work,—that is, if the circuit is composed solely of conductors, without the interposition of any apparatus which puts the current to any use,—the resistance is entirely passive. These considerations explain and justify the use of the word *resistance* applied to that property of reducing the intensity of the electric current which the conductors possess.

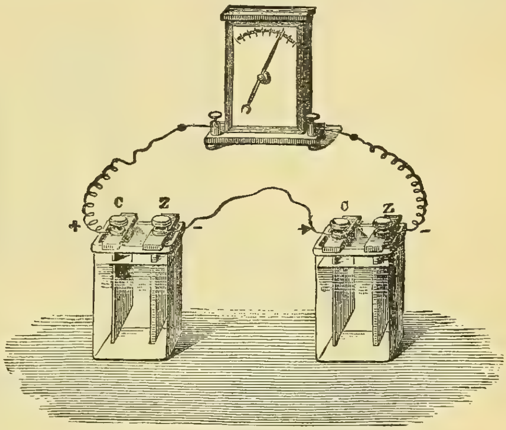


FIG. 40.

Electro-motive Force.—The cause which produces the electric current we have called electro-motive force. In order to give a clear idea upon this point force, we will adduce several experiments:—

If a battery cell be taken and the current which it produces caused to act upon a galvanometer, we shall then see that the needle is deflected; for instance, toward the right. If we change the communications of the battery with the galvanometer the direction of the needle's deflection will be altered, which shows that the direction of the current in the galvanometer has been changed,—if we now consider the first conditions: the needle deflected toward the right.

If now a second battery cell, differing in no way from the first, be taken and inserted in the circuit, and the negative pole of this second attached to the positive pole of the first, the two currents will flow in the same direction and join each other; we find that the intensity of the re-

sulting current is increased, and consequently the deflection of the needle is greater. In these conditions the two battery cells are *joined in intensity*, forming (Fig. 40) a battery of two cells. A battery of any number of cells could thus be formed, as stated before, but this is not the point upon which we wish to insist; we desire only to call the expression *battery cells joined in intensity*, and to determine the exact meaning.

Suppose that we now insert a second cell in the circuit of the first, but uniting the positive pole to the positive pole and the negative to the negative in such a manner as to have two poles of the same name ending at the galvanometer (Fig. 41).

Under these conditions the needle will remain stationary. This is not to be wondered at if it be remembered that the two cells tend to

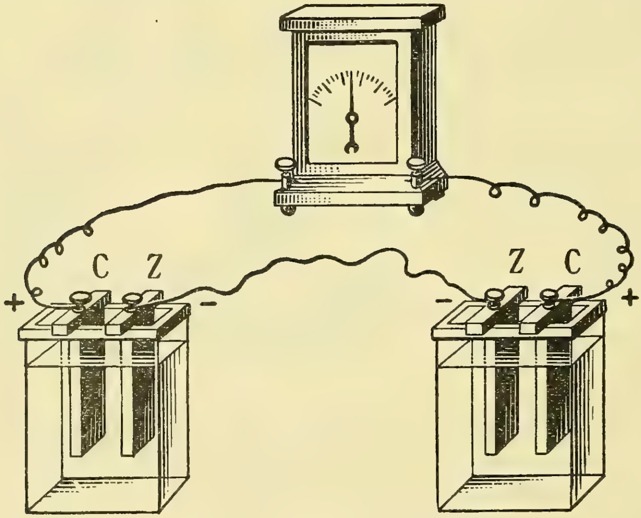


FIG. 41.

produce equal currents in opposite directions. The fact that these currents balance each other and that there is no movement either in one direction or the other is quite natural. It is said in this case that the two battery cells are opposed to each other, or are *joined in opposition.*

We have assumed, in the above, that the opposed cells were of equal dimensions. Each one acting alone would produce the same deflection of the needle, one toward the right and the other toward the left; both acting simultaneously in opposite directions cause no deflection whatever, which is quite natural and easily understood. Let us vary the experiment, and place in the same circuit (Fig. 42) a small voltaic cell, in opposition to a larger one of the same nature. We find that the needle will remain stationary, thus showing that there is no current. This result will appear strange to the uninitiated reader, and deserves to be dwelt upon. If made to act separately, they cause the needle to deflect, one

toward the right, the other toward the left. The current furnished by the larger one is more intense than the current produced by the smaller one, as the deflections of the needle show. But if these two cells be opposed to each other, the effect of one is counterbalanced by the effect of the other, and no current flows through the circuit. The conclusion of this experiment is that the electro-motive force of battery cells does not depend upon their dimensions. Experiments also show clearly that the electro-motive force of battery cells does not depend upon their dimensions, but upon the materials used in their composition.

Measurement of Electro-motive Forces.—It has been seen how, by means of an ordinary galvanometer, the electro-motive forces of different

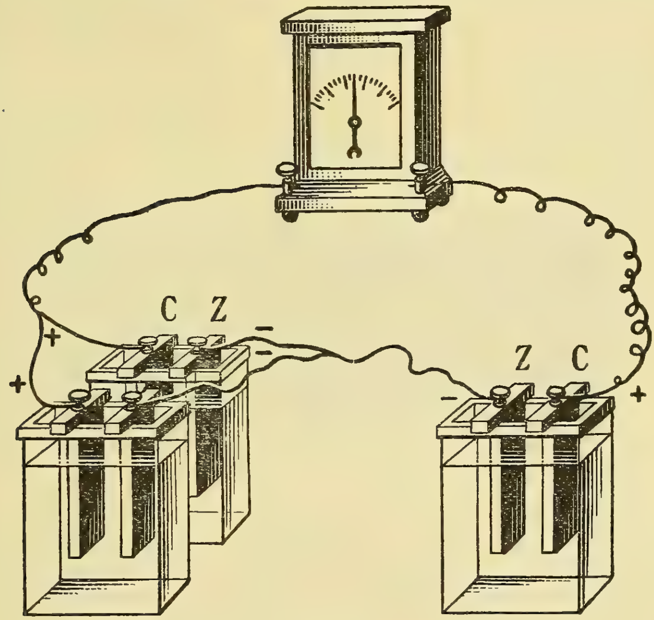


FIG. 42.

batteries may be compared. This method, just used and described, is called the *method of opposition*, because it consists in opposing equal or unequal forces. It can be easily understood how the electro-motive forces of different cells may thus be measured and tables of these forces made out. The electro-motive forces inserted between two dissimilar metals are altered by every change in their temperatures, but the connection between the change of temperatures and the change of electro-motive force has not been thoroughly investigated.

Electro-motive force may also be produced by electricity in motion, and by magnetism in ways which we cannot even describe, until the simpler phenomena of electricity in motion and of magnetism have been described; but it may be said generally that all causes which have the

power of altering the distribution of electricity can produce electromotive force or difference of potential. Every source of electricity must, as such, be able to produce a difference of potential; since no charge of electricity whatever can be made sensible without some difference of potentials, between the charged body and the earth, of neighboring conductors.

Internal Resistance of the Battery.—From the foregoing remarks it has been seen that the conductors outside of the battery offer a certain resistance to the electric movement, or, in other words, a resistance to passage of the current. Experiments show that the battery itself offers a resistance to the current it produces. From several of these observations it has also been concluded that batteries have an internal resistance in themselves, and that the resistance increases with the distance between the electrodes in the liquid, and diminishes when the immersed surfaces are increased.

If the battery be considered as a force-producing machine, it is not to be wondered at that it at the same time produces force and offers a resistance to that force. This condition is common to all machines; a part of the force they produce is absorbed by those passive resistances resulting from the action of the different parts of the machine. In a steam-engine, for instance, the friction of the steam in the pipes, the friction of the piston in the cylinder, etc., etc., cannot be avoided. This resistance of the battery has to be taken into account in nearly all cases, for the explanation of phenomena and for the calculation of results.

It can be seen that, of two batteries in which the electrodes are of unequal dimensions, the distance between them being equal in each, the one having the larger electrodes offers less resistance than the other; and it can be said, in general, that larger cells, when compared with smaller ones, offer less resistance, because the increase of surface of the electrodes is greater than the increase of the distance between them. This resistance of the batteries varies with the nature of the liquids in which the electrodes are immersed. It can be easily understood that all liquids have not the same specific power of resistance.

Connection of Voltaic Cells Abreast.—We have seen (Fig. 41) how two battery cells of the same kind may be placed in opposition to each other in such a manner as to counterbalance each other. Let us now take away the galvanometer that we had placed in the circuit of these cells, and we shall still have two cells *joined in opposition.*

Let us consider the two cells thus joined. If the galvanometer be put into communication, on one hand, with the wire connecting the two positive poles and, on the other hand, with the wires connecting the two negative poles, the passage of a very strong current will be observed. The currents of the two cells, which were at first opposed to each other, now flow together in the galvanometer. The two battery cells are then said to be *joined in quantity.*

The metallic piece which connects the two zinc poles may be considered as the negative pole common to both cells and the other as the positive pole common to both cells. It may be observed that the two cells ought to produce the same effects as a single one, in which the electrodes would have a double surface, while the distance between them would remain the same.

The internal resistance offered by the two cells is only half of that offered by each one alone, while the electro-motive force remains the same. This may be demonstrated by placing a third cell, of the same size and kind, in opposition to these two cells joined in quantity. The galvanometric needle does not deflect, which shows once more that the electro-motive force does not depend upon the size of the electrodes, but solely upon their nature.

There is, finally, a third way of joining these two cells, namely, joining them in intensity, of which we have already spoken. This manner consists in uniting the positive pole of one of the cells to the negative pole of the other. In this arrangement the electro-motive force

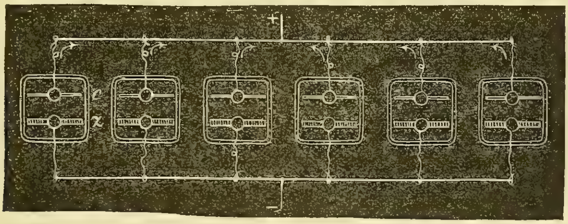


FIG. 43.

of the two taken together is double that of each separately; the resistance is also double.

These different ways of joining battery cells may be applied to any number of cells. If six cells be taken, for instance, and joined in intensity, the electro-motive force of one cell being symbolized by E and its resistance by R, it is evident that a battery of six cells joined in intensity will have an electro-motive force equal to 6 E and a resistance equal to R. If all be joined in quantity (Fig. 43), the electro-motive force of the battery will be E and the resistance $\frac{R}{6}$.

If they be joined by twos in intensity and threes in quantity, the electro-motive force will be 2 E and the resistance $\frac{2}{3}$ R. They may, finally, be joined by threes in intensity and by twos in quantity; the electro-motive force will be 3 E and the resistance $\frac{2}{3}$ R. As long as, in the last combination, there is no connection with any outside circuit, the three cells on the right are in opposition to the three on the left. It is not necessary for me to dwell longer upon the subject, or to make calculations which are, indeed, very simple, to enable the reader to understand

that, with a sufficient number of cells, a battery may be as great, and its resistance as little, as may be desired.

Voltameter.—Before entering upon the study of some of the batteries, it would be well to study a few of the effects they produce. Of all the chemical actions that can be brought about by means of electric currents, the decomposition of water is the most striking. It is done in an apparatus called the voltameter.

Two wires or plates of platinum are placed parallel with each other in a jar containing dilute sulphuric acid. These two electrodes pass through the bottom of the jar, and are attached to binding-screws or terminals to which the wires of a battery are fastened. If a sufficiently energetic current be made to pass in this apparatus, bubbles of gas will be seen to free themselves from the surface of the electrodes. If these gases be collected in proper gas-measuring jars, oxygen will be found in one and hydrogen in the other.

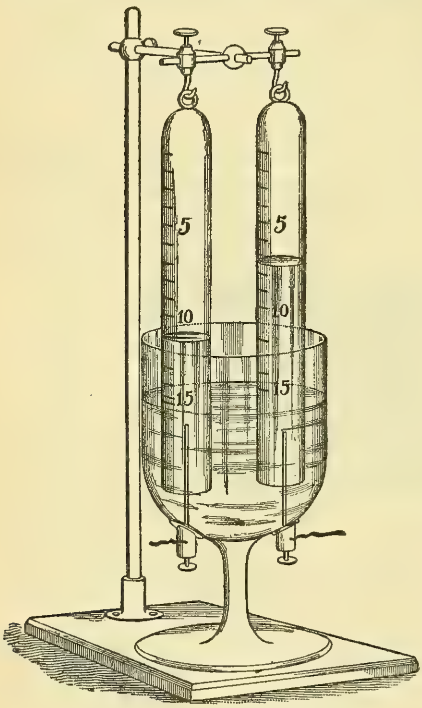


FIG. 44.—A VOLTAMETER.

The electrode by which the current enters the apparatus is called *positive electrode of the voltameter.* It is that which is connected with the positive pole, or, in other words, with the negative electrode of the battery, that furnishes the current. The negative electrode of the voltameter is connected with the negative pole, or positive electrode or generating electrode of the battery. The oxygen which appears upon the positive electrode of the voltameter is termed electro-negative; the hydrogen which is seen at the surface of the negative electrode of the voltameter is termed electro-positive.

In general, every liquid decomposed by the passage of an electric current is called an *electrolyte*, and it is said to be *electrolyzed* so long as the electric action continues. Faraday established, by numerous experiments, the laws of definite electrolysis. Without going into details, suffice it to say that two or three cells joined in intensity produce a current used to electrolyze water; for instance, for each chemical equivalent of hydrogen set free in the voltameter there will be an equivalent of zinc dissolved in each cell of the battery. The law of Faraday

may be said to be the equivalent of chemical work in all parts of the circuit.

If the experiment be made with six cells, instead of with three as indicated above, the quantity of hydrogen set free in one minute will be much greater. An idea of the quantity of electricity is thus obtained, and it can be understood how the instrument called voltameter permits one to measure this quantity. It owes its name to Faraday, who was perfectly justified in so calling it, as it is in truth an instrument of measurement. The same cannot be said of the galvanometer, which it would be better to call galvanoscope; for, in general, it does not measure the intensity of the current which passes through it, and it is only by means of complicated contrivances that any measurements can be obtained from its indications.

Much to our regret, this instrument (voltameter) is not convenient for use. It is unreliable regarding the indications, and often produces false results, on account of the resistance which it introduces into the circuit. It also presents other causes of error.

It is possible to attach a specially-calibrated scale to a galvanometer so that the readings shall be brought directly into current. A galvanometer that has been calibrated in this way is called an ammeter (ampère-meter). From it one can read off the scale milliampères or thousandths of an ampère, and often obtain fairly accurate results.

SECONDARY CURRENTS.

Polarized Electrodes.—If the voltameter be submitted for a short time to the action of a current its electrodes acquire remarkable properties, which may be recognized in the following manner: If the wires are detached connecting the voltameter to the battery, and then connected with the voltameter and a galvanometer, the galvanometric needle will be seen to deflect, thus making manifest the passage of a current furnished by the voltameter. The direction of the current is such as to show that that which was the negative electrode of the voltameter in the experiment with the battery has become, in the experiment with the galvanometer, the positive pole of this new source of electricity. In other words, the current flows in one direction in the first case and in the opposite direction in the second. It may be said that the voltameter has been charged with part of the current of the battery, and returns this current in the contrary direction.

It has been said that the *electrodes are polarized;* which is true, for they have been rendered capable of acting as poles. This is the origin of the expression which we have already used,—polarization of the electrodes. The current furnished by the polarized electrodes of the voltameter in the conditions indicated above is called a secondary current, the voltameter acting as a secondary battery. The secondary current thus obtained lasts but a short time; its intensity is seen to diminish

rapidly from the moment it begins to circulate in the galvanometer, and is soon reduced to nothing.

Polarization of a Voltaic Cell.—Let us now turn to the consideration of the objections to the earlier forms of batteries. It will not be difficult to understand the origin of their drawbacks, and how they have been overcome. An ideal battery should maintain a constant electro-motive force through the whole time of its action; its resistance should be as slight as possible; the materials of which it is constructed should be such as not to become rapidly changed in their character during its action, so that its life may be as long as possible; and there should be little or no chemical action going on when the circuit is broken, so that the entire energy of chemical change shall be concerned in or incident to the production of the current. The first forms of batteries, which were single-fluid batteries, failed to meet any of these requirements.

The following instructive and striking experiments illustrate to us the principal difficulty in the way of meeting the first: If the current furnished by a voltaic cell (one of Wollaston's, for instance), with well-amalgamated zinc, be examined by means of a galvanometer, the intensity is seen to diminish from the moment the circuit is closed. This diminution is very rapid if the circuit have but very little resistance; it is, on the other hand, very slow if the circuit offer great resistance. If, after having allowed the current to flow for five minutes, for instance, the circuit be left open for five minutes, it will be seen, when again closed, that the current has nearly assumed its first intensity. It can be said, then, that the battery when not at work regains its initial power.

From these observations it has been shown how it is possible to use the sand-battery for a number of years in the telegraph service, the telegraph lines offering great resistance, but only requiring intermittent currents. By closer observation we find that, while in the circuit, different circumstances of the phenomenon will be seen which will throw a great deal of light upon the causes to which it must be attributed. At first bubbles of hydrogen are seen to form themselves upon the copper electrode, as we have already stated; this will lead to the belief that imperceptible bubbles form themselves upon the entire surface in such a way as to interpose more or less completely, between the electrode and the liquid, a gaseous layer. Thus, apparently, the principal cause of the diminution of the intensity of the current should be sought at the surface of the copper electrode.

The following experiments will serve to demonstrate this: If, after a marked diminution in the deflection of the galvanometric needle, the electrodes be shaken without lifting them out of the liquid, the current will be seen to partly recover the force it has lost. The same is observed if the liquid alone be shaken without moving the electrodes, and, consequently, without changing the extent of the immersed surface. The moving of the copper electrode alone will show, as a result, the recovery

of the lost force. On rubbing the copper—without taking it out of the liquid—with a small brush the same result is noticed.

In these three experiments we find that the disappearance of the bubbles of hydrogen from the surface of the conducting electrode is accompanied by a renewal of the intensity of the current. If, on the other hand, the zinc electrode alone be agitated, no perceptible modification in the decrease of the current takes place.

Consequently, there can be no doubt as to the importance of the phenomenon which takes place on the surface of the copper electrode. This diminution of intensity just observed may be attributed to two causes: either to the increase in the internal resistance of the battery, or to the decrease in the electro-motive force; in fact, the two causes are present at the same time. That the resistance increases cannot be doubted, since the active surface of the copper electrode is diminished; but a simple and direct demonstration of this does not seem easy to obtain. That the electro-motive force is diminished is extremely easy to prove. For this experiment the method of opposition is employed which we have already described,—and a method which is as convenient for the comparison of electro-motive forces as are scales for the comparison of weights.

The instant the electrodes are immersed in the liquid and the battery begins to work, the electro-motive force attains its maximum intensity. Take two identical battery cells and close the circuit of one of them for five minutes, leaving the other inactive. At the expiration of that time, place the one that has been working in opposition to the fresh one, and interpose a galvanometer in the circuit, and the result will show the superiority of the electro-motive force of the fresh cell. If, now, these two cells be made to act separately, each upon itself,—that is, without the insertion of any resistance,—for five minutes, it will be found, at the end of that time, by placing them in opposition, that the second one still possesses greater electro-motive force than the first one.

It can also be shown that the electro-motive force of a voltaic cell can, by constant action, be reduced one-half. It is admitted that the diminution in the electro-motive force of batteries is due to the production of an electro-motive force (upon the surface of the negative electrode) contrary to that of the principal current. This view is founded upon the facts which have been advanced about the electro-motive force found in a voltameter, from electrodes of which gases are given off.

It may be shown by a direct experiment that the conducting electrode of a weakened battery has acquired peculiar properties. It is only necessary to immerse in the liquid a second plate of copper and to connect the two with a galvanometer. The passage of a current is thus made manifest, and its direction shows that the copper plate acts as the soluble electrode, or electro-positive, when compared with the other, which assumes the part of a conducting electrode, or electro-

negative. This current decreases from the moment it is established, and soon becomes imperceptible. Thus the electrode which was electro-negative in the voltaic cell before and during its weakening is electro-positive in the test-cell of two copper electrodes. Finally, if after the above experiment the voltaic cell be re-established, the electrode assumes its original intensity, at least for a moment, and then begins to weaken again, as in the first instance.

It is then that the conducting electrode is said to be in a state of *polarization.* Such is the phenomenon of the polarization of the negative electrode of batteries, a knowledge of which is so important. We know that the slighter the polarization the better the battery. There is still much scope for improvement in batteries, although much attention and ingenuity have been concentrated upon securing for them constancy of current and absence of polarization. The principal aim of inventors has always been, and still is, to *depolarize the electrode.*

It has been established that the *polarization* remains the same when the size of the cell and the intensity of the current are in proportion to each other. It is here necessary to define polarization. Polarization is the difference between the electro-motive forces in a polarized battery and the electro-motive forces in a depolarized battery.

It can be understood, indeed, that the quantity of hydrogen given off upon the negative electrode is in proportion to the intensity of the current, and that, if this quantity distribute itself upon the surface of an electrode also proportional, the degree of thickness of the deposit will be the same over the entire surface, and consequently its intrinsic action will not have changed. The practical conclusion of this law is that polarization will be less in a battery having larger electrodes than in one with smaller electrodes, though the total resistance be the same.

Polarization in a Battery of Several Elements.—So far, each time the polarization of the negative or conducting electrode of cells has been spoken of, the existence of one cell only has been tacitly implied; and, further, that the current which produced the polarization was the current of the cell itself. Under ordinary circumstances this is not so; several elements are generally joined in intensity, and the current which flows in each one is furnished by the entire battery.

If we place ten cells, each having ten units of resistance, in a circuit of one hundred units (total resistance, two hundred units) it is clear that the current will be more intense than if nine of the ten cells were taken away; consequently, the current which produces the polarization in each cell will be more energetic than if there were only one cell. The result is that its weakening due to polarization is more marked in cells which are joined in intensity than in separate cells.

Explained otherwise, when a current passing through a cell is more energetic than the current which the cell itself produces, the weakening of the current takes place under the following circumstances: At first,

hydrogen is given off upon the copper, and produces that which we have termed polarization of the cell. But afterward, when the greater part of the acid is converted into sulphate of zinc, the sulphate itself becomes electrolyzed, and the reduced zinc deposits itself upon the copper. If, at last, this deposit cover the entire surface of the copper, it can be easily seen that the two electrodes will become identical, and, consequently, it is no longer a battery cell. Cases have been adduced, experimentally and otherwise, where some cells of a battery not only cease to produce current in the right direction, but actually produce a reverse current.

The Study of Batteries and their Classification.

We have now reached a point where it is possible to study the different batteries and to draw comparisons between them. Up to this time we have studied only the voltaic battery and the modifications in its arrangement. Let us now take a look into those batteries, which have sprung up from the first cell, analogous to, but differing more or less from, its germ (the voltaic cell).

It will be seen how Volta, notwithstanding his imperfect means, had the happy thought to choose the elements which have been used ever since.

What are the essential conditions of a good galvanic cell? 1. It should have high electro-motive force. 2. It should have low internal resistance, so that no energy should be wasted within the cell. 3. It should give a constant current, and thereby prevent polarization. 4. The material for its consumption should be cheap and readily obtainable. 5. The cell should require no inspection or supervision to keep it in good order until all the energy of its chemical affinities is exhausted. 6. The form and dimension of the cell should be convenient, and no noxious chemical products should be formed on it by action.

No battery or one form of cell fulfills all these conditions; but as there are many varieties, it is possible to select certain cells as especially adapted to particular purposes and compare them by their standard. A great many cells have been devised from time to time, and, in order to place them in their proper category, it is necessary to classify them. The following is the latest scientific classification: 1. The closed-circuit batteries. 2. The open-circuit batteries. 3. Batteries without a depolarizer. 4. Standard of electro-motive force.[1] 5. The storage battery. 6. The medical galvanic batteries of several makes.

What is the distinction between an open- and closed- circuit battery? It has been seen[2] that the inconstancy of the current furnished by a battery through a fixed resistance is largely accounted for by polarization

[1] Several specimens of each of the classified batteries will be described and studied.

[2] Some of these descriptions of cells are taken from the valuable little work on Primary Batteries, by H. S. Carhart, A.M., of Michigan. 1891.

due to cell. That which stops polarization, either by removing the hydrogen as fast as it is formed or by preventing altogether its disengagement, is called a *depolarizer.* The distinction between open- and closed- circuit batteries depends chiefly upon the nature and action of this depolarizer.

A battery is entitled to be included in the closed-circuit type only when it is capable of working in a closed circuit of moderate resistance for a considerable period with but slight diminution in the intensity of the current. The difference is thus clearly established, between it and those cells that are adapted to stand on open circuit, without wasteful local action, and that furnish current only at intervals and then only of a few seconds' duration.

In a closed-circuit cell the depolarizer must act with sufficient promptness and efficiency to completely prevent polarization, thus removing this cause of the decrease in the current.

In open-circuit batteries the depolarizer may, indeed, be entirely absent, or it may act with so much sluggishness as to be unable to prevent polarization taking place to some extent during the action of the cell, but it destroys polarization after the circuit has been again opened. The promptness with which a cell recovers from a depression of its electro-motive force by polarization is a good criterion of the efficacy of this class of depolarizers. Batteries provided with such depolarizers occupy an intermediate position between those with a promptly-acting one and those with none at all, of which the simple voltaic element is the type. The more-efficient depolarizers, in general, are liquid; the less-efficient or slower-acting ones, with only a few exceptions, are solid. The first class must be employed when a continuous current is required, especially if the current is of considerable strength. If but a small current is taken from a cell through a high resistance, then a solid depolarizer will suffice. But batteries with no depolarizer for the removal of hydrogen, or an equivalent, are adapted only to open-circuit use, in which the circuit is to be closed for only a few seconds at a time.

CLOSED-CIRCUIT BATTERIES.

The Daniell Battery.—This is the battery which claims for itself the underlying principle of all constant batteries. It was invented by Professor Daniell, of Edinburgh, in 1836. It (Fig. 45) consists of a copper plate, C, dipping into a solution of copper sulphate contained in a glass or glazed, highly-vitrified, stone-ware jar, J, and a zinc plate or rod, Z, to which a copper wire or strip, W, is soldered, dipping into either dilute sulphuric acid or a solution of zinc sulphate, the two solutions being separated by a porous partition, P, made of unglazed earthenware, and called "a porous pot." The electro-motive force of a Daniell cell, with all its modifications is, roughly, 1.1 volts, but it varies from about 1.07 volts to 1.14 volts, depending upon the densities of the solutions of copper and zinc

sulphate. With *equidense* solutions and with plates of pure zinc and copper, the electro-motive force is 1.104 volts. This value is increased by increasing the density of the copper-sulphate solution, and is diminished by increasing the density of the zinc-sulphate solution, and is scarcely at all affected by the *ordinary* atmospheric changes of temperature.

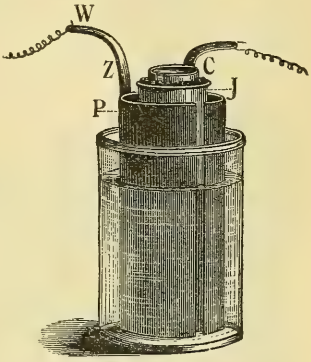


FIG. 45.—DANIELL CELL.

The Daniell battery gives a constant electro-motive force, and retains a nearly constant resistance. The resistance of the cell varies with the area of the copper and zinc plates immersed in the liquid, the distance between the plates, and the thickness and constitution of the walls of the porous cell. With a cell about seven inches high, of the relative dimensions shown in the accompanying figure, the resistance may be as low as $\frac{1}{3}$ ohm when the solution in which the zinc plate is immersed is dilute sulphuric acid of a specific gravity of about 1.15 at 15° C., while some Daniell cells with porous pots and small zinc plates are used having a resistance of as much as 10 ohms. The electro-motive force of the Daniell, or of any other form of cell, is quite independent of the size of the various parts of the cell, or of the cell as a whole, and depends solely on the materials employed in its construction.

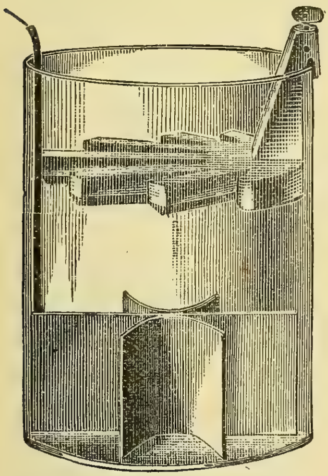


FIG. 46.—GRAVITY BATTERY.

On account of the constancy of the Daniell cell, which is caused by electro-motive force, in the practice it may be taken as a unit and can be compared with others. The British Association has adopted a unit differing very little from this one, and has given to it the name of *volt*. The cell in which the electro-motive force is exactly equal to the volt differs but slightly from that of Daniell.

The Gravity Battery.—This battery is a simple modification of the Daniell, designed to dispense with a porous cup. It takes its name from the fact that in it the zinc and copper sulphates are separated by their difference in density. One form of this battery is shown in Fig. 46. This cell always keeps in better condition if a closed circuit be maintained through a high resistance when the battery is not in use.

The Grove Battery.—The Grove battery consists of a cleft cylinder

of zinc immersed in dilute sulphuric acid (1 to 12) and a thin plate of platinum in nitric acid, contained in a porous cup. The platinum electrode, being surrounded by the nitric acid, decomposes, oxygen is set free and forms water with the polarizating hydrogen, and nitric oxide is given off. The battery thus modified is without polarization; in other words, it is constant. This battery dates from 1839.

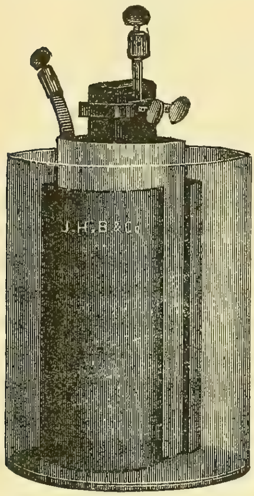


FIG. 47.—BUNSEN BATTERY.

The Grove battery has the advantage of electro-motive force and low internal resistance. Such a cell is capable of giving 12 ampères on short circuit, or through an external circuit of no appreciable resistance. Before the introduction of dynamo-electric machines and the storage battery, 40 Grove cells served for an arc light. It is found that electro-motive force is intermediate between that of a Grove and that of a Daniell battery.

The Bunsen Battery.—After the invention of the Grove battery, Bunsen modified it by substituting a prism of baked carbon for the platinum. The electro-motive force is slightly less than that of the Grove.

The Bichromate Battery.—This battery is employed very extensively in laboratories, and presents some very great advantages. The resistance is very slight on account of the short distance between the electrodes, and, moreover, the waste of the zinc is suppressed during the intervals between experiments, as it is withdrawn from the liquid; thirdly, polarization is slackened by the comparatively large surface of the carbon electrode; fourthly, the quality of the liquid is considerable on account of the special form of the lower part of the bottle; and, lastly, the charging and cleansing is extremely easy. But in spite of these advantages the battery gives a powerful current for only a short time, after which the intensity is seen to diminish. It is therefore suitable only for experiments of short duration.

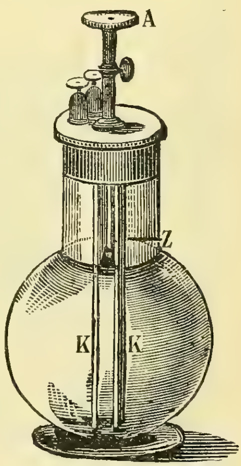


FIG. 48.—BICHROMATE BATTERY.

The accompanying cut represents one of the forms of this cell. The zinc is attached to a rod, *A*, by means of which it can be drawn out of the liquid when the battery is not in use. The carbon plates are fastened to a metallic clamp, which is attached to

the hard-rubber top of the cell. The top of the zinc is covered with an insulating strip to prevent direct contact with the carbons. Many other forms of plunge batteries have been the outcome of this invention.

The Copper-Oxide Battery.—It has been remarked that, in general, the best depolarizers are liquid. There are, however, two exceptions to this, which exhibit notable efficiency. They are the oxide of copper and the chloride of silver. Both these solids readily give up their non-metallic element to nascent hydrogen, and the reduction to the metallic state makes them excellent conductors. This copper-oxide cell was introduced by Lalande and Chaperon. It has a capacity for work per unit weights greater than any other cell, either primary or secondary.

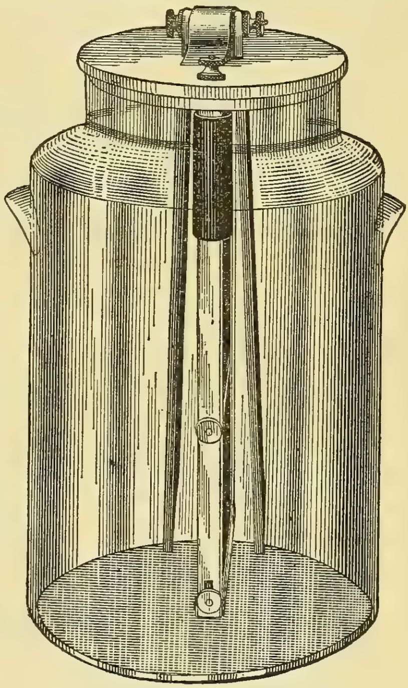


FIG. 49.—EDISON-LALANDE COPPER-OXIDE BATTERY.

Mr. Thomas A. Edison, recognizing the good qualities of the copper-oxide as a depolarizer, has devised a form designed to meet most of the objections which may be made to it. The copper oxide is employed in the form of a compressed slab, which, with its connecting copper support, serves also as the negative plate. Two of these plates are inclosed in a copper frame, on the longer arm of which is the binding-post. One or two of these copper-oxide plates are used, according to the size and capacity of the cells. The weight of the oxide plate for a 15-ampère-hour cell is two ounces, and for a 600-ampère-hour cell two pounds. The figure, as shown, is a 600-ampère-hour cell complete. The cover is porcelain, with small openings for the zinc and copper terminals. Since this cover does not exclude the air, the formation of a carbonate is prevented by pouring on top of the solution of caustic potash a small quantity of heavy paraffin-oil, so as to form a layer about one-fourth of an inch deep. If it is not used, the life of the cell is reduced fully two-thirds.

The Edison-Lalande cell has been subjected to a number of stringent tests at the Edison laboratory,[1] and is also being put to the test of doing

[1] The cuts and notes illustrating these laboratory tests of the Edison-Lalande battery are taken from the private laboratory register of Mr. Edison. I found it important to introduce these detailed accounts of this cell, that every one might judge its value for himself. It is the only perfect closed-circuit battery in existence, and can be highly recommended to the profession for all medical and surgical purposes.

hard and continuous work on the lines of telegraph, railway, and telephone companies, with the best of results. This battery is now in the hands of the most prominent men of our profession for all kinds of work. I can recommend it as the only battery for cautery and motor work. Those who have not seen it in action should certainly find an opportunity to examine it. The only drawback is in the cleansing and refilling, in which caution must be exercised on account of the caustic potash, although this difficulty is now being overcome by using sticks instead of a solution of potash. The results of these laboratory tests are shown in the curves given herewith (Fig. 50).

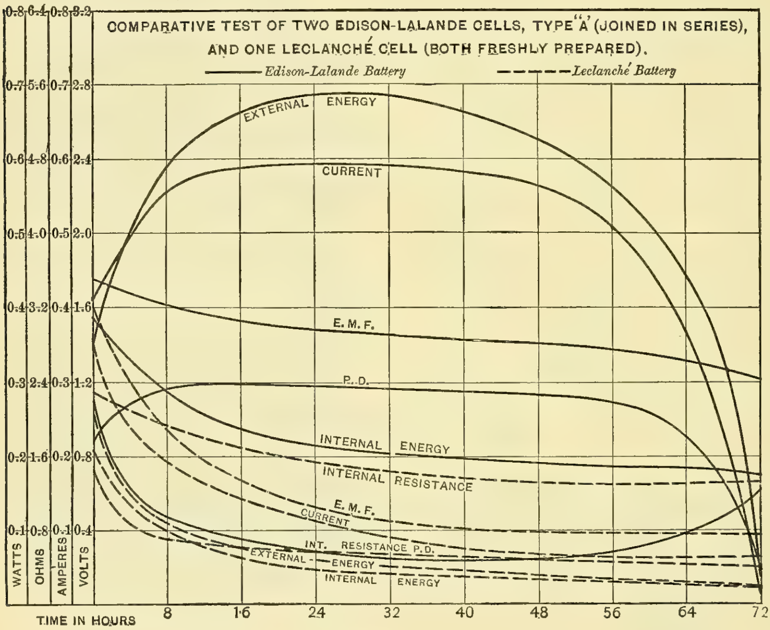


FIG. 50.

In this test the batteries were so arranged as to be alternately thrown into circuit with a resistance coil. The periods of rest and work were of five minutes' duration. When the Leclanché was resting the Edison-Lalande was working, and *vice versâ*.

The 300-ampère-hour cell, which may be taken as a typical example, stands eleven and one-fourth inches high by five and three-eighths inches in diameter. It has an internal resistance of 0.025 ohm; the electromotive force of the cell on continuous hard work is 0.7 volt, and on light work 0.75 volt. The initial electro-motive force is 0.9 volt, soon falling, however, to the normal standard, where it remains practically constant during the life of the cell. On open circuit there is little or practically no action on the zinc, and positively none when the latter is pure. The

action of the cell is admirably shown in the accompanying curves (Fig. 51). Fig. 52 represents the results of careful tests made at the Edison laboratory upon cells picked out at random from among a large number. In this test four 300-ampère-hour cells were joined in series in circuit with a resistance of 0.8 ohm, and gave the following results: Weight of zinc before test, 10,017 grammes; weight of zinc after test, 8567 grammes; total loss, 1450 grammes. Calculated loss from output, 1444 grammes; loss by local action, 6 grammes. Mean current, 2.76 ampères, 2.8 volts; total run, 298 ampère-hours. The loss was calculated as follows, taking the chemical equivalent of zinc as 0.0003367, based on the latest researches

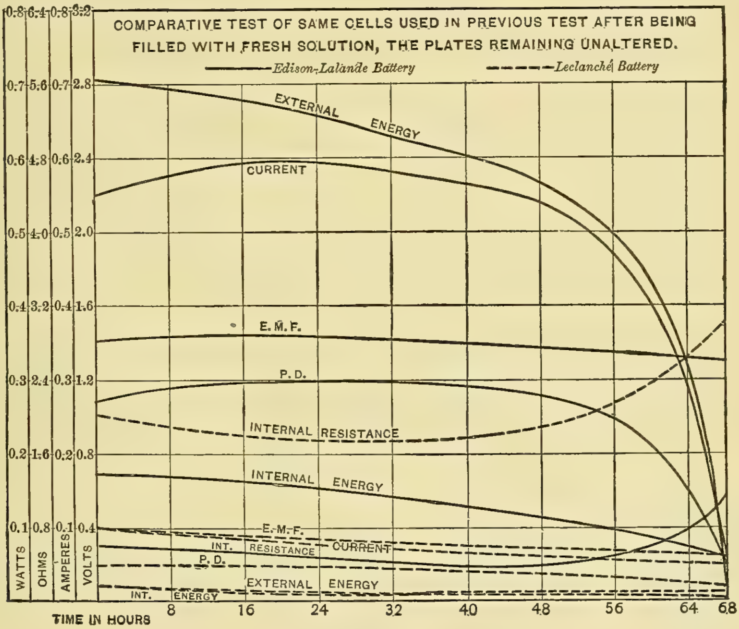


FIG. 51.

of Rayleigh and Kohlrauch: $276 \times 108 \times 3600 \times 0.0003367 = 361$; $361 \times 4 = 1444$.

Fig. 53 exhibits results of a comparative test of Leclanché and Edison-Lalande batteries in connection with Blake transmitter. Both batteries had been closed through transmitter for twenty minutes; the circuit was then opened, and the increase in electro-motive force was noted at regular intervals.

The test as here shown extended over a period of one hundred and eight hours, and both the current and electro-motive force remained practically constant. It will be noted, however, that the external available energy continued to increase for nearly half the period of the test, owing to the almost constant decrease in the internal resistance of the

cell, which is also evidenced by the curve representing the internal energy, which fell rapidly from the start.

This decrease in internal resistance is due to the fact that the reduction of the oxide of metallic copper at the surface of the negative plate causes the formation of an excellent conducting surface, the production of which, however, requires a few hours' work in a cell freshly set up. In the latest form of the *Edison-Lalande cell the improvement has been effected* of reducing a thin film of copper on the oxide superficially, before placing in the cell, to make the initial internal resistance lower. In reading the figures at the left those referring to the watts, ohms, and volts must be divided by four in order to reduce them to the corresponding values for one cell. During the test the cells were connected through a resistance of 0.8 ohm.

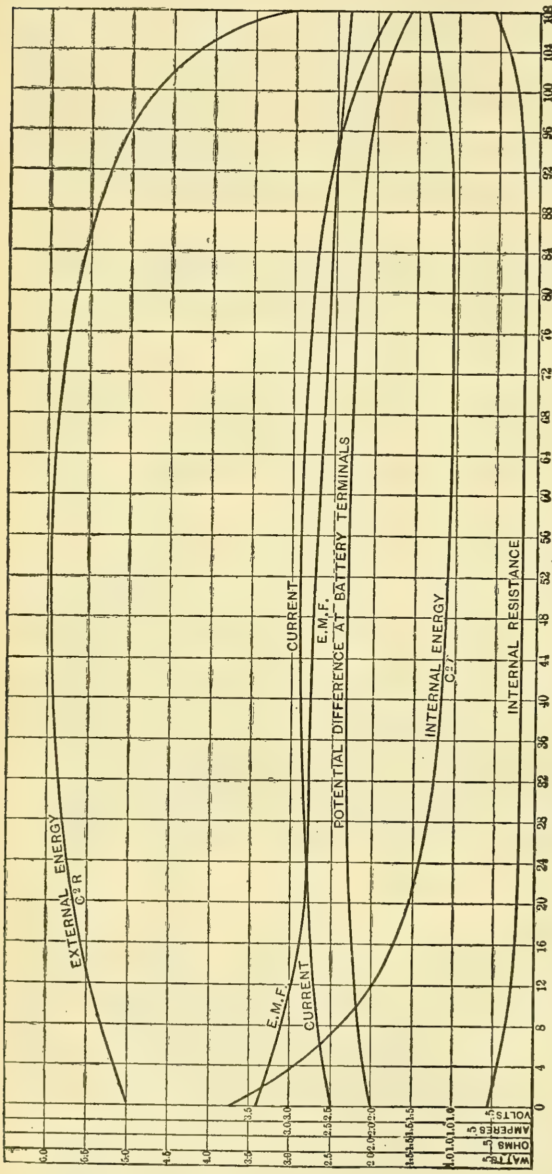


Fig. 52.

I am convinced that wherever this battery is used it will prove itself possessed of undeniable advantages over all others.

The Chloride-of-Silver Cell.—Marie Davy appears to have been the first to suggest the use of silver chloride as a depolarizer (about 1860), although it owes its present prominence to the investigations of Warren de la Rue.

The elements are zinc and the silver chloride, the latter of which is readily reduced to metallic silver by nascent hydrogen. The exciting fluid of De la Rue's battery is ammonium chloride, and contains 23 grammes to 1 litre of distilled water.

The initial electro-motive force of a silver-chloride cell is about 1.1

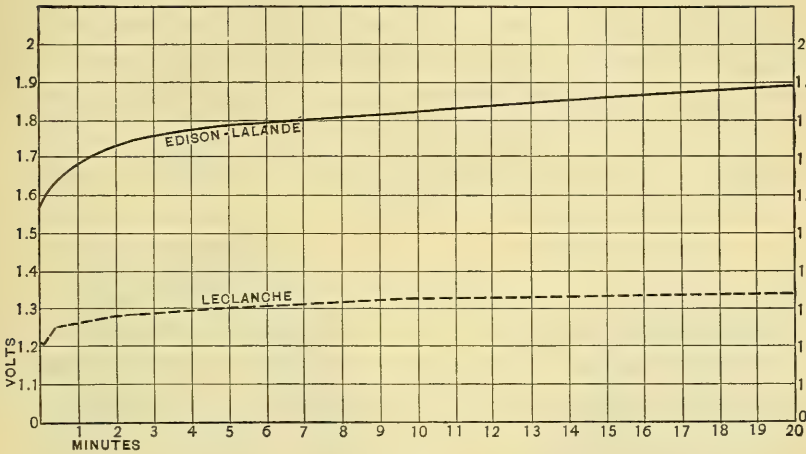


FIG. 53.

volts. Its internal resistance falls rapidly upon first closing the circuit, on account of the reduced silver. It polarizes but slightly, and recovers promptly. It is employed chiefly for testing purposes. It is now much used by physicians. The Gaiffe and other chloride-of-silver batteries are very extensively used for induction coils, or to furnish continuous currents for medicinal purposes. This is a small cell, hermetically closed in ebonite boxes having screw-tops. This battery is transportable, and has no free liquid, the two electrodes being separated by six or eight sheets of blotting-paper saturated with a solution containing 5 per cent. of chloride of zinc. Gaiffe formerly employed powdered chloride of silver, but he now seems to prefer the melted silver. There are also other forms of this battery on the market.

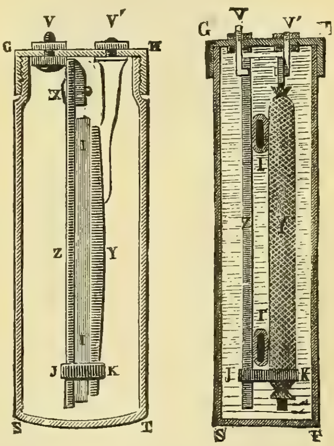


FIG. 54.—GAIFFE CELL.

Among other varieties of the closed-circuit batteries may be mentioned the Gethius, Delany's modified gravity cell, Sir William Thompson's tray battery, the Fuller bichromate battery, the Partz acid-gravity battery, and the Taylor battery.

OPEN-CIRCUIT BATTERIES.

The Leclanché Cell.—This one stands at the head of the open-circuit batteries in which a solid depolarizer is used. It bears the name of its inventor, Leclanché. The metallic oxide had been proposed as depolarizers previous to the invention of this cell, but without practical results. Thus, with zinc in dilute sulphuric acid and platinum, surrounded by the peroxide of lead in a porous cup, Brets found an electro-motive force of 2.4 volts. During thirty minutes' short circuit this fell to 1.4, but recovered, after five minutes' rest, to 2.16. It is evident that this high electro-motive force is due not only to the oxidation of the zinc, but to that of the hydrogen as well, both chemical processes contributing to the electro-motive stress in the same direction. The chief disadvantage

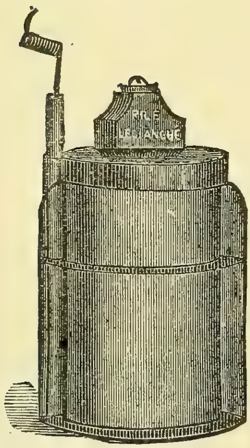


FIG. 55.—LECLANCHÉ CELL.

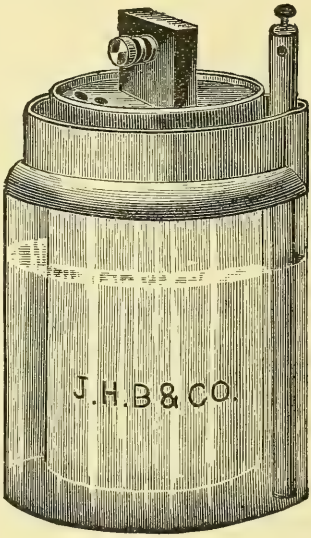


FIG. 56.

in the employment of lead peroxide as a depolarizer lies in the fact that the reduced lead is converted into lead sulphate. This accumulates on the negative pole, and has the effect of largely increasing the internal resistance of the cell.

The typical Leclanché cell with its porous cup has a glass jar, molded with a lip, and in it the zinc rod is placed. The carbon plate is usually surmounted by a lead cap cast on the carbon and holding the binding-post of the positive terminal. The cut exhibits a new connection, designed to avoid corrosion of the lead cap. The size of the zinc rod, which never exceeds half an inch in diameter, indicates larger internal resistance, and shows that the cell is designed to furnish only small currents through considerable external resistance. The amount of energy held potentially in the cell is represented approximately by the weight

of the zinc. The exciting liquid is ammonic chloride. The initial electro-motive force of the Leclanché cell varies from 1.4 to 1.7 volts, and the internal resistance from about 0.4 to 2 ohms.

There are several modifications of the Leclanché cell on the market, each one possessing an advantage or a disadvantage over the other. Three of these, as the prism Leclanché, the closed Leclanché, Leclanché with carbon cup, are shown in Figs. 56, 57, and 58.

Among the open-circuit batteries there are several known to us of the Roberts peroxide battery, the sulphate-of-mercury battery, and the Fitch chlorine battery. They all have their special uses.

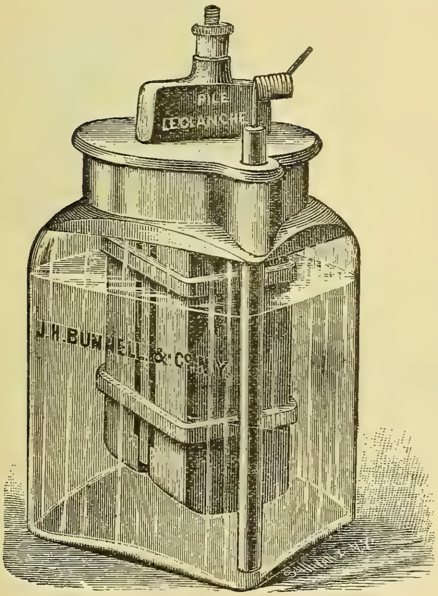


FIG. 57.

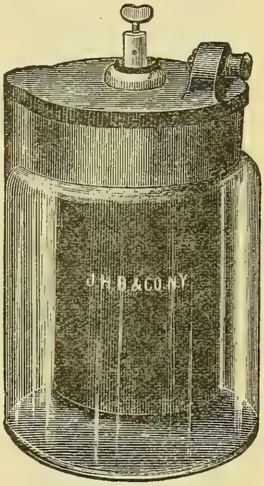


FIG. 58.

BATTERIES WITHOUT A DEPOLARIZER.

The Smee Cell.—This is the oldest battery of any practical value without a depolarizer. The positive plates of this cell are zinc, inclosing between them, with proper insulation, a negative of thin silver corrugated and covered with platinum in a very finely divided state. The excitant or electrolyte is dilute sulphuric acid; and the purpose of the roughened surface of the silver is the mechanical dislodgment of the hydrogen as fast as it is released at the negative plate, hydrogen being found to be much more easily detached from a rough surface than from a smooth one.

The Law Battery.—Among batteries without depolarizers may also be found the Law battery, the diamond carbon battery, the cylinder carbon battery, and the Gassner dry battery, all known to us.

The Gassner Cell.—One of the oldest cells of the dry type without a depolarizer is that of Dr. Gassner. The zinc composing the positive element is the containing vessel. It is usually covered with paper, or inclosed in a paper box. The negative element is carbon, and occupies about one-half the space in the cell. The paste, which is filled in between the zinc and the carbon in the Gassner cell, is made of a composition. The initial electro-motive force of this cell varies but little from 1.3 volts. It polarizes very rapidly on so low an external resistance as 5 ohms, while the internal resistance, which is different for cells of different size, is very irregular during the working of the cell. Such a cell should be employed only for intermittent service, where the circuit is kept closed for short periods only. In such situations it will doubtless prove efficient and durable. Its convenience, particularly in the hands of unskilled persons, is much in its favor.

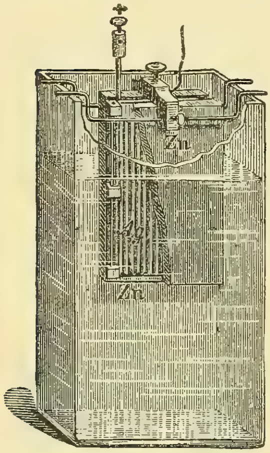


FIG. 59.—SMEE BATTERY WITHOUT DEPOLARIZER.

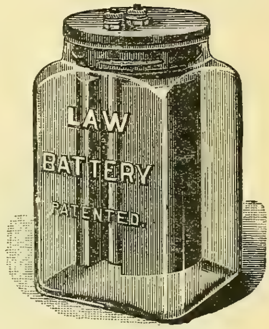


FIG. 60.

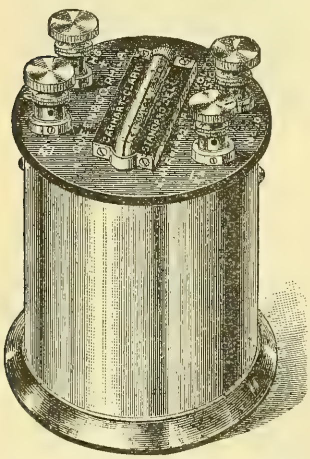


FIG. 61.—CLARK STANDARD CELL.

BATTERIES WHICH HAVE STANDARD OF ELECTRO-MOTIVE FORCE.

The *Latimer-Clark cell* is one of the best specimens of the standard cell. The metallic elements are pure zinc in zinc sulphate and pure mercury. The normal electro-motive force of this cell is 1.45 volts at 66° F., diminishing very slightly as the temperature rises. The Latimer cell is the most useful one for testing, although it is used almost solely for the purpose of supplying a reliable standard of electro-motive force. It possesses a remarkably constant electro-motive force, and the amount of its variation between different cells is generally exceedingly small.

The original Clark cells exhibited certain abnormal and irregular values, both of electro-motive force and temperature coefficient. A

thorough investigation of it was therefore undertaken by Lord Rayleigh, and the results published. His investigations gave birth to another cell named after him, the Rayleigh cell. There are also several other standard cells known as the oxide-of-mercury cell, described by M. Gouy in 1888; Sir William Thompson's standard Daniell cell, Lodge's standard Daniell cell, Flemming's standard Daniell cell, and the chloride-of-lead standard cell.

STORAGE BATTERIES.

In another part of this work I have already said that a voltameter submitted to the influence of an electric current for a moment becomes capable of furnishing a current contrary to the exciting current. This capital fact has enabled me to show, under one of its plainest forms, the phenomenon of the polarization of electrodes.

The current furnished in this manner by the voltameter is a secondary

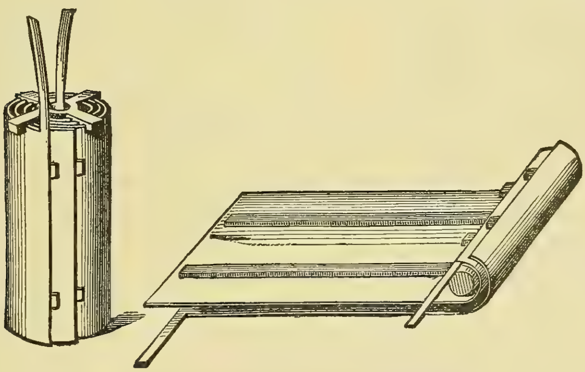


FIG. 62.—GASTON PLANTE SHEET.

current, and the apparatus becomes a secondary element. The current may be said to have been furnished by the battery and returned by the secondary element. The study of this question dates from the investigations by Gautherot, as early as 1801. Shortly afterward the first secondary battery was devised by Ritter, of Jena. Following on the invention of the voltaic pile, it has been found that if an oblong strip of wet paper has its extremities in contact with the poles of the pile each half of the slip will be electrified, and if it be removed from contact with the pile by a rod of glass or other non-conductor its electric state will continue. This was observed by Volta, and, according to Dr. Lardner (writing in 1841), was the means of suggesting to Ritter the idea of his secondary pile, which consisted of a series of discs of a single metal, alternated with cloth or card moistened in a liquid by which the metal would not be affected chemically. If the extremities of such a pile be put in connection by conducting substances with the poles of an insulated voltaic pile, the pile will receive a charge of electricity in a manner similar

to that produced by the band of wet paper, one-half taking a positive and the other a negative charge, and after its connection with the primary pile has been made it will retain the charge it has thus received. The secondary pile, while it retains its charge, produces the same physiological and chemical effects as a voltaic apparatus.

In 1859 M. Gaston Plante made a secondary cell based upon the principles above briefly sketched. Instead of plates of platinum he used plates of lead, rolled as shown in illustration (Fig. 62). The consequence was that, when the current passed through these plates, the oxygen produced at one plate combined with the metal and deposited lead oxide; the hydrogen, as before, remaining free on the other plate. By this means a cell was produced, in which, after the charging current was removed, the elements of lead and lead oxide remained. These being connected yielded a current for a short time; only, however, on account of the little of the oxide produced,—a mere film on the surface. Plante thereupon devised his so-called "forming" process, which consisted in first charging his plates, then discharging, then charging again with the battery current reversed, and so on, increasing intervals of rest being left between the operations, until finally he produced, through the repeated oxidation and subsequent reductions of the oxidized material to a metallic state, very porous or spongy plates. These, by reason of their porosity, exposed a very large surface to the oxidizing action of the current, so that the result was the same as if he had charged a plate of great superficial area.

We know that when batteries are connected in multiple arc—that is, all the zinc plates together and all the copper plates together—then the plates of each kind act as one larger plate, the surfaces of all being connected. Plante found that if he charged a number of secondary cells connected in this way, and, after the charging, arranged his cells in series, —that is, the positive plate of one connected with the negative plate of the next, and so on,—he could obtain very powerful currents for short periods of time.

In 1880 M. Camille Faure covered Plante's lead plates with red-lead, and then put them in little flannel jackets. The peculiarity of the red-lead is that, on sending a current through it, it is easily changed into spongy lead; so that, instead of the "forming" operation taking weeks and months, it can be done in a few days, or even hours. This discovery apparently removed the chief obstacle to Plante's cell becoming of commercial value, and, when announced, was hailed as an extraordinary advance in electricity.

Since 1880 a great many patents have been obtained for secondary batteries, and they now exist in many forms. Mainly, however, the efforts of inventors have been directed to reducing the weight of the cells and to devising new ways of holding the red-lead on the plates. Brush packs his red-lead, or other active material, in a frame of cast-lead

containing slots, cells, or openings. Sellon also made a plate with receptacles for containing and holding the active material.

The storage battery at the present time is simply a subject for further research and invention. No form of it exists in which grave defects are not observable. The value and efficiency of many of the cells offered on the market have been overestimated and often greatly misunderstood, and we find none more eager to grasp at possible improvements than those who to-day most loudly proclaim the great merit of their own particularly-advertised contrivances. This not infrequently represents the hope that the large amount of capital already risked may, by some stroke of good fortune, be redeemed.

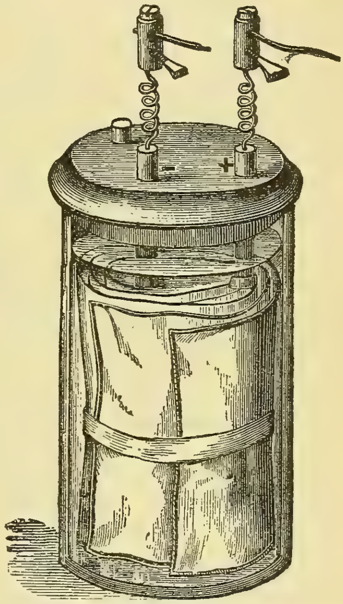


FIG. 63.—FAURE'S MODIFICATION OF THE PLANTE CELL.

The commonest defects of the storage cell are "needling," "buckling," and "disintegration." "Needling" is the formation of the so-called "lead-tree,"—fine spiculæ of metal between the electrodes, which cause short-circuiting and rapid waste of current. "Buckling" is the deformation or bending of the plates themselves, by which one plate often comes in contact with another, and short-circuiting again follows. "Disintegration" and "buckling" also are usually due to chemical changes in the electrodes; the plates, disintegrating in time, drop to pieces. Besides these difficulties certain solutions cause very high internal resistance in the cell, as well as a variety of other disadvantages.

One of the best forms of storage battery is that devised by Mr. Willard E. Case, in which he uses a neutral liquid, from which he deposits metal on one electrode while peroxidizing the other. Mr. Case's investigations in the storage battery have led him to the remarkable discovery that heat can be directly converted into electricity in the galvanic cell. He places in his cell an electrode of tin, an electrode of carbon, and a liquid which at ordinary temperature will not attack either electrode; therefore, no current is yielded. But as soon as the liquid is warmed—and to do this the cell, which is hermetically sealed at the outset, is merely put into hot water—chlorine is set free from the liquid, and attacks the tin. Then the current starts, and continues until all the tin is converted into chloride. Now, if the cell be allowed to cool, the chlorine will release the tin and return to the liquid, and the cell regains its original state. The chlorine, in fact, is a chemical pendulum, swing-

ing from liquid to tin, again from tin to liquid, as often as the heat is applied and removed. Of course, the cell lasts indefinitely; theoretically, forever. No material is exhausted in it. The temperature is never above that of boiling water. Its electro-motive force is about $\frac{1}{4}$ volt.

In one sense this cell may be regarded as a heat-storage battery; it is really a wonderful, efficient heat-engine, and is not merely a most beautiful, ingenious illustration of the relation and interconvertibility of the natural forces, but an advance apparently destined to be of the highest practical value.

Electrolysis.

Definition of Electrolysis.—The decomposition of a chemical compound, called the *electrolyte*, into its constituent parts by an electric current.

Under the heading of "Voltameter" much has been said regarding electrolysis, but, owing to its importance, I devote another special part to it. We find that in a galvanic battery a chemical reaction takes place,

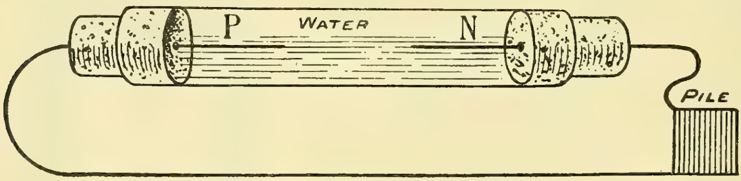


Fig. 64.—Glass Tube and Water.

and the result is the production of an electric current. If, conversely, we place in a decomposable liquid two conducting bodies, and thus enable a current of electricity to pass through the liquid, we shall find that the result is a chemical decomposition. This decomposition by means of the electric current is called electrolysis; the liquid decomposed is known as an electrolyte; and the two conducting bodies are termed electrodes. In a galvanic cell a definite amount of chemical action evolves a current and transfers a certain quantity of electricity through the circuit; so, conversely, a definite quantity of electricity, in passing through an electrolytic cell, will perform a definite amount of chemical work. An electrolytic cell is, therefore, the converse of a voltaic cell. The discovery of the decomposing effects of the electric current was made by accident, and followed almost immediately after the invention of Volta's pile. A series of brilliant discoveries followed within a few years, which at that time were as notable, and many of them as far reaching, as those more recent. One of the earliest and most important of these, because it opened up an entirely new field of research, was the decomposition of water by means of the battery,—an experiment first made by two Englishmen, Messrs. Nicholson and Carlisle. It formed the ground-work of nearly all that was accomplished during the first twenty years of this

century, and it is worth describing in Mr. Nicholson's own words. He says :—

" On the 2nd May (1800) we inserted a brass wire through each of two corks inserted in a glass tube of half an inch internal diameter. The tube was filled with new river-water, and the distance between the points of the wires in the water was one inch and three-quarters. This compound discharger (meaning one of Volta's modified batteries) was applied so that the external ends of its wire were in contact with the two extreme plates of a pile of thirty-six half-crowns, with the corresponding pieces of zinc and pasteboard. (This is the material the Volta battery was made of.) A fine stream of minute bubbles immediately began to flow from the point of the lower wire in the tube which communicated with the silver, and the opposite point of the upper wire became tarnished, first deep orange and then black. On reversing the tube the gas came from the other point, which was now lowest, while the upper, in its turn, became tarnished and black. . . . The product of gas during two hours and a half was two-thirtieths of a cubic inch. It was then mixed with an equal quantity of common air and exploded by the application of a lighted waxen thread.

" Platinum was used instead of the brass wires, and gas was liberated at both poles. When collected separately and examined, one proved to be hydrogen and the other oxygen. Other experimenters substituted salts of copper and lead for the water, and found in each case that the pure metal was deposited at one of the poles. These were the beginnings of electro-chemistry."

The names of Humphry Davy, Cruikshank, Ritter, Nobili, and Faraday must always be at the head of the list as pioneers in this branch of the study. To Faraday we owe very much. Three years later, after his discoveries in magneto-electricity, he supplemented these with the investigations which established the laws of electro-chemistry. He found that the amount of chemical action in the cell is always proportional to the quantity of electricity passing through it, and that the quantities of substances dissolved and set free by electrolysis are in definite proportions by weight, and these proportions are identical with the ordinary chemical equivalents of the substances. From the first law we know that a current of a certain strength will always liberate just so much hydrogen, for example, from water, and will cause the solution of just so much zinc in the cell whence the current is derived. To illustrate the second law: Nine grains of water, for example, contain eight grains of oxygen and one grain of hydrogen, and hydrogen and oxygen always combine in these proportions to form water. Now, if we tear apart, so to speak, the constituents of water, we shall always find eight grains of oxygen at the positive electrode and one grain of hydrogen at the negative electrode. Why this happens is not definitely proved, but is the generally accepted theory, that of Grotthüs.

Grotthüs's Theory of Electrolysis.—Explanations regarding what takes place during electrolysis has been frequently attempted, but, beyond more or less probable hypothesis, nothing has been proved. This is not surprising when we consider that the nature of electricity itself is unknown to us. Grotthüs (1805) gave the following explanation of electrolysis: He supposes, in the chemical constitution of water, an atom of hydrogen to be united to an atom of oxygen;[1] that these substances have certain natural electrical tendencies or conditions, hydrogen being a positive body and oxygen a negative body. Whilst constituting water, these natural electricities neutralize each other and hold the two atoms together, the two forces being then in equilibrio. Directly, however, a particle of water is exposed to the influence of the voltaic series, this equilibrium is overset or disturbed, and a particle, *A* (Fig. 65), at the positive extremity, *P*, will have its oxygen atom, *O*, drawn toward *P*, and its hydrogen atom, *H′*, repelled from it. The one (oxygen) is, by the hypothesis, an electro-negative substance, and the other (hydrogen) an electro-positive substance. Conversely, a particle of water, *B*, at the negative extremity, *N*, of the apparatus, will have its hydrogen atom,

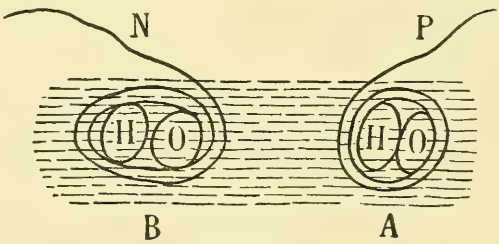


FIG. 65.

H, drawn toward *N*, and its oxygen atom, *O′*, repelled from it.[2] The two elements of the water will be so far loosened in their state of chemical union. A similar result will ensue in the next succeeding particle of water by the influence of the atoms *H′* and *O′*, and so on through all the intermediate conducting chain between *A* and *B*; that is to say, we shall have what has been termed a polar electrical series, in which all the positive electricities look one way and all the negative electricities the other,[3] as indicated by the positive and negative signs in the next figure, in which *A P* represents the anode, or positive electrode; *C N* the cathode, or negative electrode; *A*, *B*, *C*, *D* being successive particles of water made up of the gases oxygen and hydrogen, *O*, *H*, and in opposite electrical states, as denoted by the signs + and —. The atom of oxygen *O*, particle *A* (Fig. 66), being, as it were, thus loosened in its combination with

[1] Dalton supposes one volume of oxygen to contain as many atoms as two volumes of hydrogen; so that, although we suppose the gases united atom to atom, still, taken as volumes, they are united in the proportions of 1 to 2.

[2] Rudimentary Electricity (16), p. 13: "Similar electricities repulse and opposite electricities attract each other."

[3] *Ibid.* (38), p. 45.

the hydrogen atom *H*, the positive wire, *P*, by neutralizing its negative electrical energy, may either combine with it or set it free altogether under the form of gas. Similarly, the negative wire, *N*, may set free the hydrogen, *H*. Directly, however, the first oxygen atom, *O*, is evolved, and its associate hydrogen, *H*, left alone, then this same hydrogen, *H*, effects a decomposition of the next particle of water, *B*, unites with its oxygen atom, and, again forming water, sets the next hydrogen atom free; and so on through the whole chain of electrical action, up to the last particle of water, *D*, at the negative wire, *N*, where an atom of hydrogen, *H*, is finally dismissed altogether in yielding up its positive electricity to the negative wire. We may easily conceive a series of decompositions and recompositions converse to this, from *N* toward *P*, thereby causing a mutual interchange of opposite electricities and a final evolution of the two gases at the opposite wires, *P*, *N*, by the continued action upon successive particles of water in contact with them.

Faraday called these migrating atoms *ions*, and gave the name

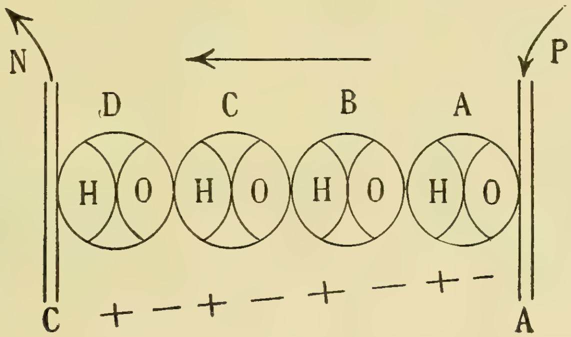


FIG. 66.

anode to the positive plate and *cathode* to the negative plate. Then the ions which went to the anode were termed *anions*, and those which appeared at the cathode *cations*. Two years after Faraday had made his discoveries, De la Rue observed the singular fact that in a peculiar form of Daniell battery the copper plate became covered with a coating of metallic copper, which took the exact impress of the plate, even to the fine scratches upon it. In 1837 Dr. Golding Bird decomposed the chlorides of sodium, potassium, and ammonium, and deposited their respective metals on a negative pole of mercury, thus obtaining their amalgams. This opened up the great industries of electrotyping, electroplating, etc.

Medical Batteries.

Requirements.—The batteries for medical purposes should supply a constant continuous current, and should admit of the elements being joined and used in any desired order. Then the inactive elements should consume no material, and finally all noxious fumes should be avoided.

Before we proceed to the description of the batteries themselves, we will describe an apparatus by means of which any number of elements may be inserted and removed from the circuit. Such an apparatus is shown in Fig. 67. The elements are joined in series, and from each connecting wire another wire leads to the metal strips 0 to 10. The clamp, *D*, is movable along the metal bar, *C*. The binding-screw *A* is connected with the metal strip 0, and the binding-screw *B* with *C*. By moving *D* the elements may be inserted and put out of circuit. This is a very simple apparatus, and is only a specimen of the many different types that are manufactured by surgical-instrument makers. Every electric-battery company or firm have some special contrivance attached to their batteries or separate. So we have a large variety to choose from.

We find it of the utmost importance to recommend a good battery to medical men. This is a hard task. Nevertheless, we shall try and place here, before their notice, such batteries as will answer all the purposes for which they could possibly be required; at the same

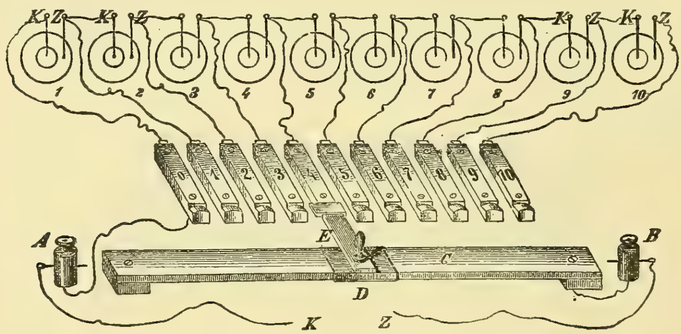


FIG. 67.—APPARATUS FOR COUPLING ELEMENTS.

time be portable and cheap, and not require constant and frequent attention. It is very difficult as yet to combine all these properties in one battery. If many patients are treated, it will be found that two or even more separate outfits will be required. Where, however, it is possible, bring your patient to the battery rather than carry about a portable one; where it is not possible, the question of a portable battery must be made the first object. All kinds of small and portable batteries are to be had on the market; they have them from 10 to 60 cells, arranged in cases fitted with commutators, current-collectors, galvanometers, etc. A few of these, which bear a reputation from their practical usage, are illustrated and described.

The Waite & Bartlett plug-and-socket battery has a wide field of usefulness.

A very respectable reputation is borne by the chloride-of-silver dry-cell batteries as practical, portable apparatuses. They differ essentially from all others, obsolete as well as yet-existent forms, in not only

the particular way and manner the silver chloride itself is applied to electrical work,—insuring compactness, efficiency, constancy, and durability,—but also the fact that the cells themselves, dry and free from liquid, are always ready for use without further attention until their elements are completely reduced and exhausted.

A 50-cell galvanic battery that has an electro-motive force of more than 50 volts, with electrode-cords, rheostat, tray, and mahogany case 6 x 7 x 10 inches, weighs eleven pounds. From a point of cleanliness we

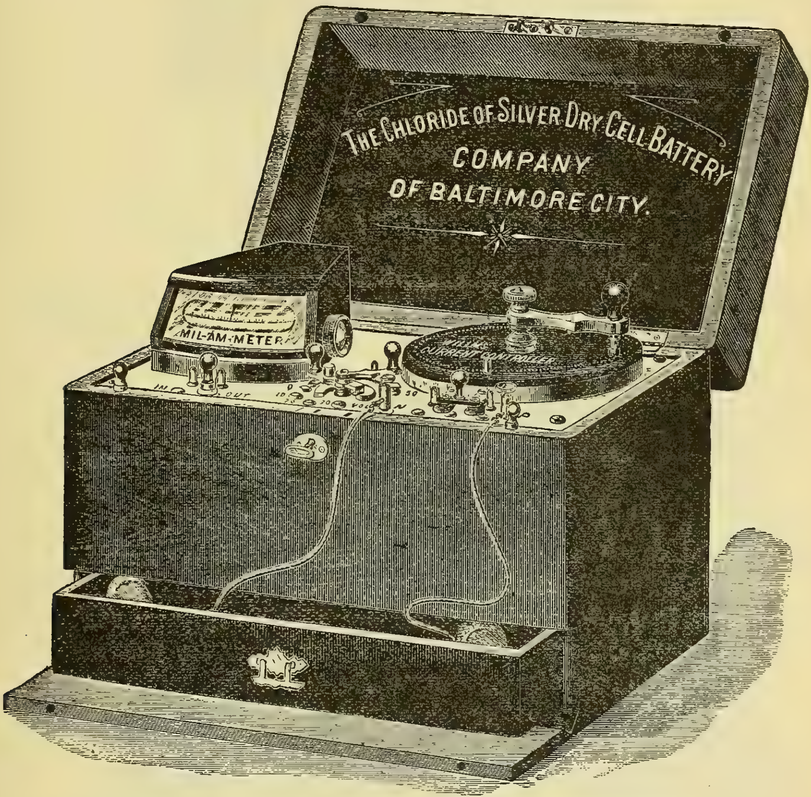


FIG. 68.—FIFTY-CELL SILVER-CHLORIDE GALVANIC BATTERY.

find that, from the absence of all liquid and the hermetical sealing of the cells, this battery must remain in that state. These cells give a constant and uniform current. Steady work does not weaken their strength of current. These batteries are made from 6 to 50 cells or more. Each instrument consists of a number of chloride-of-silver dry cells, hermetically sealed, arranged in series, and encased in a japanned metallic box to themselves, leaving nothing exposed but the connecting pins and nuts securing them to the box-top, as shown in Fig. 69, which represents the inner, removable, cell-case of a constant-current galvanic battery.

When the elements are exhausted this metal case with contents is the part which is renewed,—a matter of mere exchange of one set of elements for another; so simple that no time is lost and labor greatly

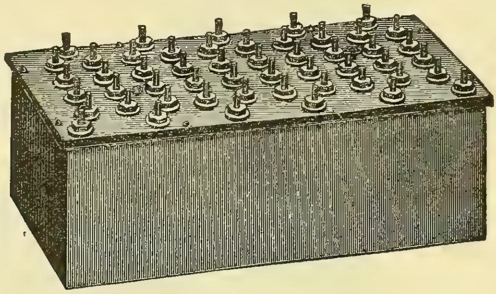


FIG. 69.

economized thereby. The cost of renewal is but 30 cents for each galvanic cell.

These inner cell-cases are now placed in hard-wood finished and polished outer battery-boxes, from which they can be readily removed at any time by lifting-studs; and are finally covered by loose, hard-

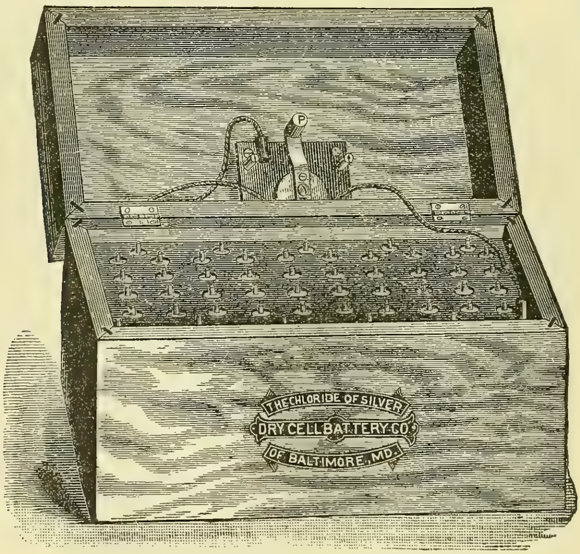


FIG. 70.

rubber plates, through which the connecting pins themselves alone project. Each of these top plates is regularly numbered from 0 up to total number of cells in the battery. Fig. 70 shows the complete battery as described; box open, ready for work.

Leiter's Battery.—Leiter's movable manganese-ore battery is said

to be cheap, to give a sufficient, strong, and constant current, and to be easily managed. One of the elements is shown in Fig. 71.

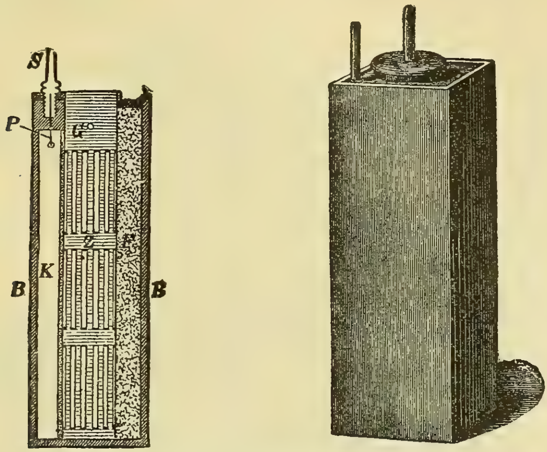


FIG. 71.—COMPLETE CELL.

The cell, *B B*, is made of gutta-percha, and contains a gutta-percha cylinder, *G Z*, which holds the zinc rod. *K* is the carbon block; the

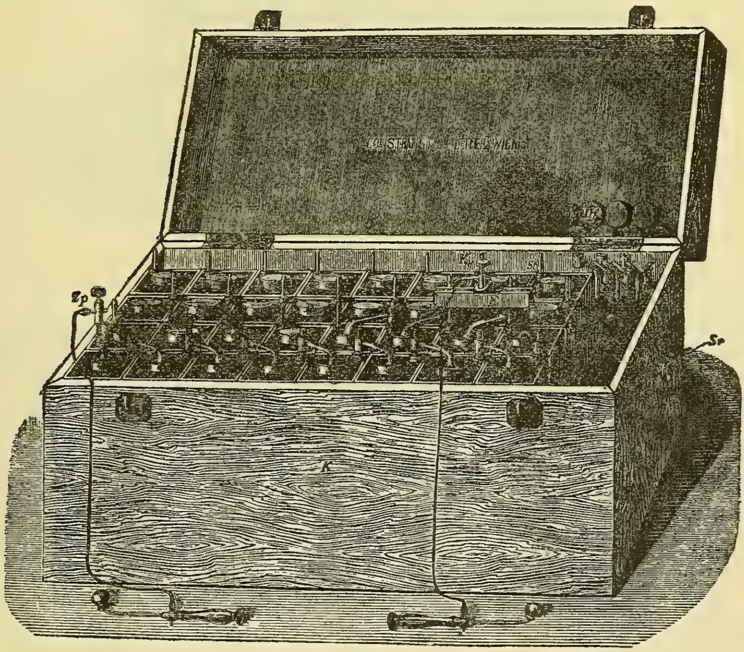


FIG. 72.

remaining space is filled with manganese ore (manganese dioxide) and pieces of carbon. A platinum wire, *P*, connects the carbon with the zinc

piece, S, which represents one of the poles of the element. A solution of sal ammoniac is used. The manganese ore and carbon pieces are separated from each other by a layer of asphalt. A number of elements joined up to form a battery are shown in Fig. 72.

The J. Kidder Manufacturing Company makes also a very suitable portable galvanic apparatus. This, like others, has several things to recommend it: The patent, improved attachments for electing various cells without interrupting the circuit when the slide is moved. This is an important factor in some cases. By moving one of the levers, the current is alternately closed and interrupted. Also, the current can be

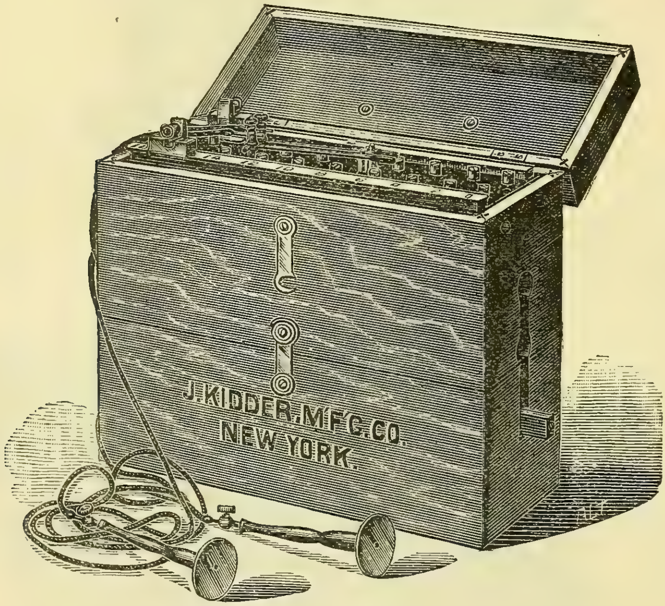


Fig. 73.—Kidder Portable Battery.

thrown rapidly and alternately in opposite directions. Fig. 73 shows the complete Kidder portable battery; Fig. 74, the cell arrangement.

The McIntosh portable galvanic battery has been in the service of the profession for a number of years, and has proved itself sufficiently valuable to merit consideration in this work. This battery is constructed on an improved plan. The zinc and carbon plates are arranged in couples and securely clamped to hard-rubber plates with thumb-screws. Thus any of the couples can be removed by simply loosening a screw. The thumb-screws are also used for binding-posts. By this manner of connecting, the plates are brought nearer together than in any other battery, thus giving less internal resistance. The cells are made in sections of six and a drip-cup composed of one solid piece of hard rubber. By this arrangement one section can be handled, emptied, and cleaned

as easily and quickly as one cell. It also prevents the liquid from running between the cells, as is the case when single cells are used, and danger of breaking, as is the case with glass cells. The drip-

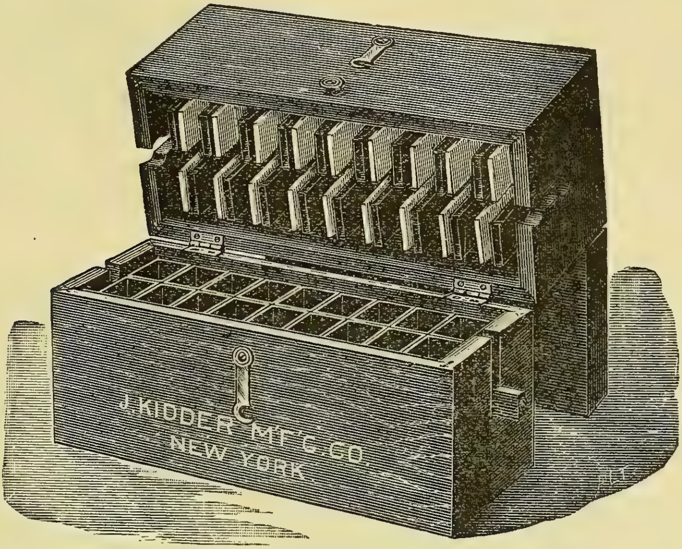


FIG. 74.—CELL ARRANGEMENT.

cup on the side of each section of cells is to receive the zinc and carbon plates when removed from the cells.

Fig. 75 shows the hard-rubber plate of a section (on the under surface of which is cemented a sheet of soft, vulcanized rubber) and binding-posts which project through the hard and soft rubber and screw into the

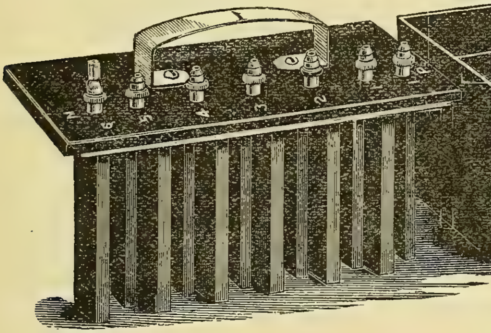


FIG. 75.

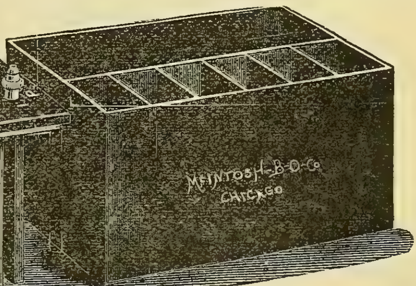


FIG. 76.

brass piece holding the zinc and carbon couples. The rubber plate on which the couples are clamped projects over on one side enough to cover the cells when the zinc and carbon plates are placed in the drip-cups. When the cells are not in use, and the lid of the battery-box is closed, it

presses on the spring-handle of the section (Fig. 75) and holds the soft rubber firmly over the cells and drip-cup. By this arrangement the hydrostat is made water-tight.

Fig. 76 shows a section of 6 cells and a drip-cup made of one piece of hard, vulcanized rubber. The drip-cup is to receive the zinc and carbon couples when not in use. By the aid of a simple current-selector any number of cells can be used. (See cut.) They are made from 6 to 24 cells.

Enough has been said regarding portable apparatuses. The specimens described and illustrated are only a few of the good ones, and sufficiently enough to select from.

STATIONARY AND CABINET-STAND APPARATUSES AND BATTERIES.

When portability is not taken into consideration the difficulties in settling upon the choice of an electric appliance are greatly lessened, for 60 large cells suitably arranged will give off sufficient current-power for all electro-therapeutic purposes. When we arrange our cells to give the best effects in any given case we must not lose sight of the fact regarding their internal resistance. As to the giving of any exact figures as to the internal resistance of various batteries, I have already roughly stated it in the pages devoted to the study of batteries. That of a Daniell cell should not much exceed 1 ohm; a "sawdust" Daniell may have 10 or more ohms; a Leclanché cell may have a resistance of from 1 to 5 ohms. If any one wish to inquire into the practical and the detailed accounts of the measure currents of the resistance and electro-motive force of batteries with sufficient accuracy for this method, they will be found and described in "Practical Physics," by Glazebrook and Shaw; in the "Text-Books of Science" series; or in "Practical Physics," vol. ii, by Balfour Stewart and Gee. However, it is of importance to have some knowledge of the resistance of the battery in order to know whether, for any purpose, it is best to arrange the cells that are to band in series or in parallel. Of this something has also been said in the foregoing pages.

Let us continue what we intended saying further about stationary batteries. It is found that, as a rule, for a fixed installation for galvanic and faradic work 60 large Leclanché cells are fitted up, and these are convenient, as they require little attention and remain in good order for long periods. These cells will be of sufficient power for electrolysis, etc. For other therapeutic effects, as the electric bath, cautery, and lighting purposes, the other apparatuses already spoken of are required.

There are many very fine cabinets and stationary mechanisms sold, for use in all kinds of electro-therapeutical applications. A few of the best ones are described and illustrated.

A very fine and complete stationary cabinet-stand battery is the one shown (Fig. 77); it is made by the J. Kidder Manufacturing Company. It has a compound circle switch for electing without shock, singly,

any number of cells in the series, or for cutting out cells as desired. Also, to elect any number of cells in any part of the series. There is a current-reverser for reversing the poles of the galvanic current; also an automatic interrupter for rapidly or slowly breaking the galvanic current. This is operated by an independent battery, and so arranged as not to short-circuit the galvanic cells. A small switch controls the operation of the automatic interrupter. There are, in addition, a centre-bearing switch for the control of the galvanic current, and a circuit button. By simply raising the screw the current of any of the galvanic combinations is instantly cut off. A galvanoscope and cord-posts finish

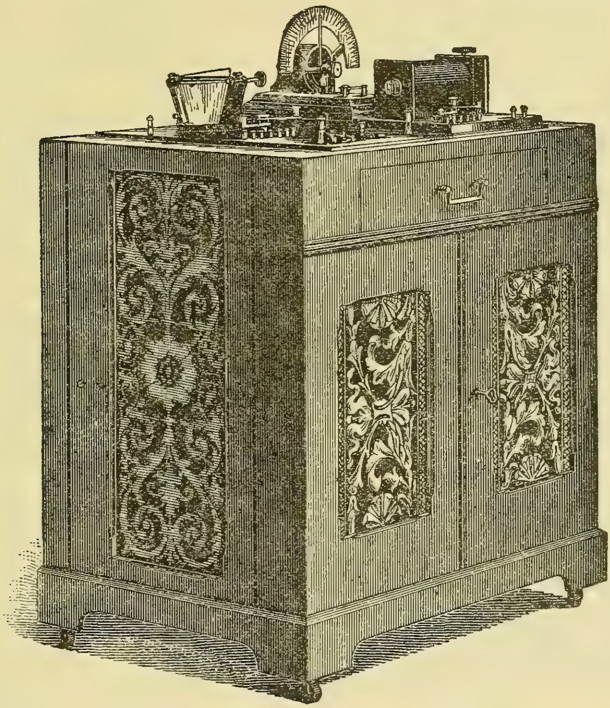


FIG. 77.—KIDDER CABINET BATTERY.

a more perfect arrangement. The faradic coil produces ten different combinations of currents. A circle switch for electing any of the various faradic combinations, a current-reverser for reversing the poles of the faradic currents, a centre-bearing switch for controlling the faradic currents, a small switch for operating the faradic coil with one or more batteries, and a vibrating device for the faradic coil are also added. When current-reversers are moved toward the left the positive pole is left-hand cord-post. Toward the right the positive is right-hand cord-post.

New Induction Coil.—In utilizing these currents of high tension and

large quantity, it is absolutely essential that we be able to increase them by almost imperceptible gradations from zero to the maximum strength required. In what are termed the separate-coil apparatus (wound for high-tension currents) this is readily accomplished by a stationary primary coil, over which are glided at will helices composed of wire of varying thickness and length. The continuous-coil apparatus, as ordinarily constructed, comprised in a single compact helix all the merits of the separate-coil apparatus with its various and cumbersome helices, with the single exception of an inability in the beginning to yield a sufficiently slight current, especially when the so-called quantity currents were used internally by the bipolar method. In the device (Fig. 78) suggested by Dr. A. D. Rockwell, and made by the Kidder Manufacturing Company, this difficulty has been successfully overcome by having a permanently-fixed helix, *A*, with a movable primary coil, *B*.

The total length of the coil of this helix is 7552 feet, with the following subdivisions: 696 feet of No. 21 wire, tapped at 116 and 580 feet; 2116 feet of No. 32 wire, tapped at 783 and 1335 feet; 4740 feet of No. 36 wire, tapped at 1740 and 3000 feet. The heavy coil of No. 16 wire

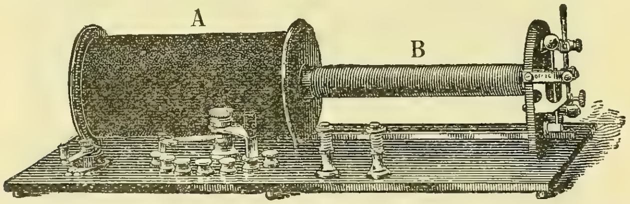


FIG. 78.—THE ROCKWELL COIL FOR CURRENTS OF QUANTITY AND TENSION.

has been discarded and the No. 21 coil so arranged as to yield a current equal to No. 16. The merit of this arrangement consists of one's ability to use the whole 7000 feet and more of wire, or to utilize, at will, each section of the coil with its subdivisions far more readily than when they are wound on separate spools, and at the same time to increase the current-strength by imperceptible gradations from zero to the maximum. So high is the resistance offered by the great length of wire in such a helix as this that a comparatively large electro-motive force is necessary to run it. Almost any form of cell can be used.

If any one of the sal ammoniac cells be used, it is a good idea to combine them in multiple arcs of two each. In this way polarization takes place much less rapidly than when they are connected in simple series, and six cells are sufficient for any strength of current desired.

It is this insusceptibility of low resisting tissues to currents of exceedingly high tension that renders this quality of current of so much value for the relief of pelvic pains of a non-inflammatory character, while the extraordinary readiness with which currents of large quantity and low tension affect these same tissues gives to them a special value in certain nutritional disturbances.

The upright cabinet made by the Galvano-Faradic Manufacturing Company is one of the finest specimens of workmanship, and is complete in every detail. It is furnished with forty or more cells of the Fitch perfect battery, which is unquestionably the best ever devised for electro-therapeutic work. The galvanic circles, with double cell-selectors, wire-coil rheostat, pole-changer, automatic rheotome, and the various switches to bring into circuit the milliammeter, automatic rheotome, and water rheostat, are mounted on a vertical base, and the faradic coils, water rheostat, and binding-posts are placed on a horizontal base of polished hard rubber, all parts being handsomely nickel-plated. The cells are arranged on shelves in the lower part of the cabinet, doors being provided so that they are easy of access. Heavy, insulated copper wires connect the cells with the buttons within the circles on the base, the wires passing up at the back of the cabinet, which may be opened and expose the connections to view. The double cell-selectors allow the operator to select any cell or cells within the circles, and to use them uniformly.

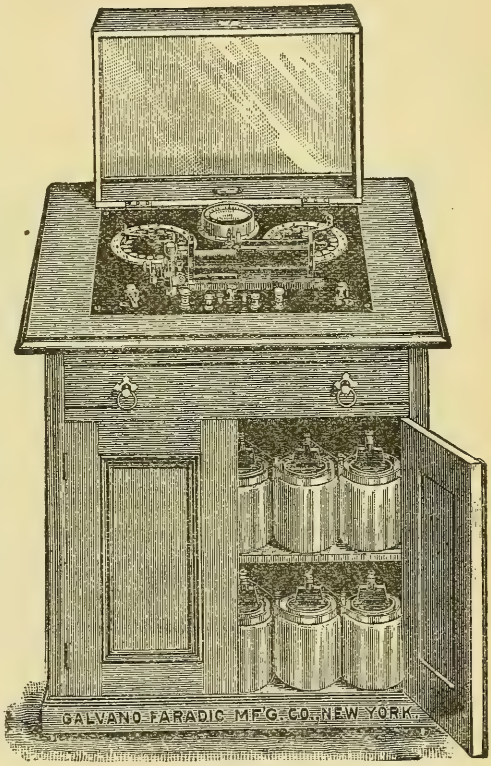


FIG. 79.

They are provided with broad-flange bottoms, and, when selecting additional cells, these slide from one button to another, always resting on one before leaving the other, so that a gradual increase of the current is insured without the possibility of a shock. The rheostat has German-silver-wire coils of from 5 to 5000 ohms resistance, a total resistance of 17,000 ohms, and may be used, in connection with the meter, to measure the resistance of the patient or to test the condition of the cells. The meter is a vertical form, which is unaffected by magnetic influences and, therefore, does not have to be adjusted. It has a scale of double values, and measures from 1 to 500 milliampères. This is placed on a bracket in the top of the cabinet, and is easily read from a distance. The

automatic rheotome gives graduated interruptions of the galvanic current. It is constructed on the principle of a clock, and is operated by a strong spring that is not liable to get out of order.

The water rheostat may be used to gradually modify the current from any series of cells. The faradic apparatus is of superior construction, and differs materially from those in common use. This consists of two parallel primary coils, to one of which a slow vibrator is adjusted, and to the other an improved form of rapid vibrator or rheotome, which is a thin metal ribbon, fastened permanently at one end and at the other attached to a screw-lever, by means of which the tension of the ribbon may be varied and the maximum number of vibrations attained, producing the most sedative effect. The Goelet system of interchangeable secondary spools are furnished, these being wound with different sizes of wire and tapped at different lengths, giving effects from seven coils. The fine coil has 1500 yards of No. 36 wire, tapped at 500 and 1000 yards; the intermediate coil has 800 yards of No. 32 wire, tapped at 300 and 500 yards; and the coarse coil has 250 yards of No. 22 wire. The coils are operated with four extra cells connected in series with a circular wire rheostat which regulates the strength of the current.

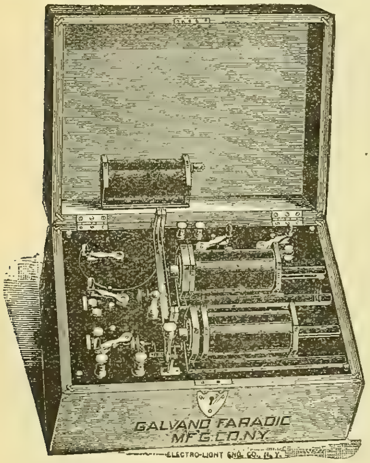


FIG. 80.

The cabinet is made of oak, carved and beautifully finished, has beveled plate-glass doors, and the inside fitted with beveled plate-glass mirrors. It also contains two large drawers in which a complete set of electrodes are tastefully arranged. The cabinet is mounted on rubber-tired wheels, making it easy to move over a carpet or a polished floor without marring.

Fig. 79 illustrates a convenient and desirable form of office battery, made by the Galvano-Faradic Manufacturing Company, of New York, for a physician in moderate circumstances. This battery is square in form, 37 inches high, 27 inches wide, and 23 inches deep. The current is supplied from forty cells of the Fitch perfect battery.

The switch-board contains the galvanic circles with double cell-selectors, milliammeter, du Bois-Reymond faradic coil, pole-changer, and other necessary switches.

This method of controlling the current obviates the use of a rheostat and also admits of the selection of any cell or series of cells and uniform use of the same.

The meter is direct reading, and measures from 1 to 250 milliampères. The faradic coil has a sliding secondary coil wound with 1000 yards of No. 32 copper wire, which is tapped at 500 yards, giving the effect of two coils, one of 500 yards and one of 1000 yards in length. It is fitted with a rheotome, giving rapid interruptions, and a slow vibrator, by means of which the interruptions may be graduated.

The advantage of the combination of secondary induction coils known as the Goelet faradic battery (Fig. 80), and manufactured by the Galvano-Faradic Manufacturing Company, is that the variations of the current to be derived therefrom render it universally useful in applying this agent (in this form) to a greater variety of conditions than was ever possible with the old forms of faradic apparatus.

To appreciate the qualities of the induced (faradic) current the fact

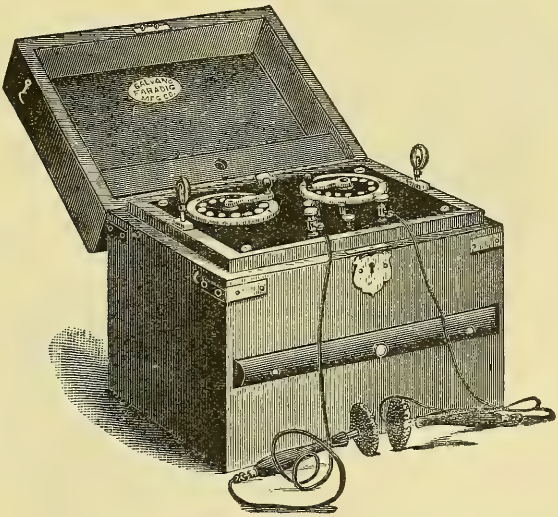


Fig. 81.

must be borne in mind that the character of this current is varied both by the number of turns or convolutions of the wire in the secondary coil surrounding the primary or core, whence the current is derived by inductive influence, and also by the greater or less resistance offered the current by the coil itself,—this resistance being greater the longer and finer the wire, and less the shorter and coarser the wire. That is, upon the variation of the two qualities, electro-motive force and volume, depends the difference in its character and its therapeutic properties. The vibrator or rheotome is of novel construction, and is an important feature of this battery. This is a thin metal ribbon, fastened permanently at one end and at the other attached to a screw-lever, by means of which the tension of the ribbon may be varied and the maximum number of vibrations attained, which is absolutely necessary to accom-

plish the object in view. This arrangement permits a wide range of variation in the number of interruptions per second.

Fig. 81 illustrates a portable galvanic battery of twenty-four cells made by the Galvano-Faradic Manufacturing Company. In the bottom of the box is a movable tray in which the cells are placed. This tray is controlled by two hinged rods which are fastened to it, and these by two lifting-rings at the ends of the rubber table. These rings, being screwed tightly down, hold the cells firmly against the hydrostat, or, being loosened, allow the hydrostat to be removed from the front of the centre of the box; they also serve as handles to lift the tray of cells.

The zinc and carbon plates are arranged in couples and fastened to a base under the rubber table. Wires connect the elements with the

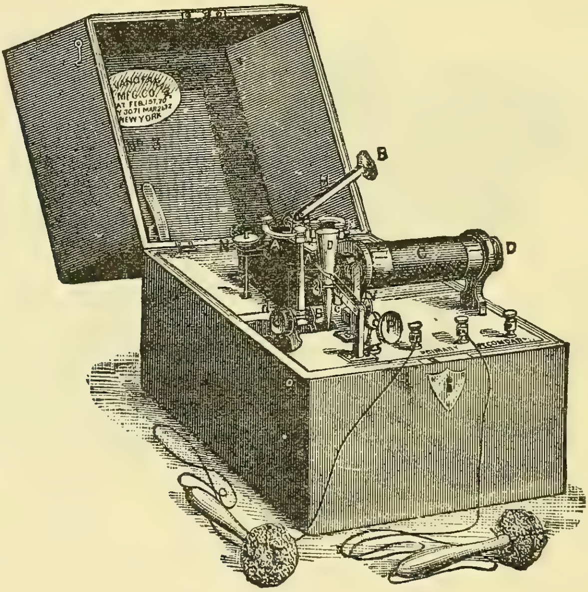


FIG. 82.

button within the circles on the rubber table, each button corresponding to a cell. These wire connections being incased, the fumes from the fluid cannot reach them; *consequently, no corrosion can take place, and the battery is always ready for use.* To use the battery, the hydrostat is drawn out and the tray of cells raised, thus immersing the elements in the fluid. To bring any required number of cells into the circuit the current-selectors are turned to the figures marked on the circles. The battery is provided with a commutator or polarity changer.

The Galvano-Faradic Manufacturing Company's No. 3 battery, shown in Fig. 82, is an excellent instrument. It has a large coil, gives three variations of the current, and has both rapid and slow vibrators, the latter being valuable in producing muscular contractions.

This can be regulated so as to give slow and distinct shocks, as well as quick vibrations, at the will of the operator.

The electrical cabinet shown on next page is one of the Chloride-of-Silver Dry-Cell Battery Company's. It is provided with 100 chloride-of-silver cells, which are capable of easily yielding a current large enough for any case in medical practice. These cells are connected up to a series of blocks in a switch, in ten sets of 10 cells each. By moving the switch, therefore, it is possible to throw in circuit 10, 20, 30, 40, 50, 60, 70, 80, 90, or 100 cells, as well as to select any set or sets of 10 cells which may be desired. This is sometimes a great advantage, inasmuch as needlessly-large resistances in the circuit for regulating the current are by its means rendered unnecessary. From this switch, which may be called the cell-selecting switch, the current is led to a reversing key, thence to a water rheostat, thence through the mil-am-meter, and finally to the main binding-post, to which the circuit cords or electrodes may be attached. Above the reversing key is another similar key, which is used for the purpose of sending into the external circuit—*i.e.*, through the patient—either a continuous (galvanic) or an alternating (faradic) current. This is done by simply shifting the key from one side to the other. The faradic current is furnished by a standard induction coil placed in the left of the cabinet; this coil is supplied with an independent battery of about six cells, and furnished with a key by means of which the current may be interrupted periodically or up to the limit of the machine. Toward the back of the cabinet, but within full view of the operator, is situated a mil-am-meter, also provided with a switch for the purpose of throwing the meter into circuit or out of circuit, as desired. This meter is furnished with three scales, reading respectively from 0 to 5, from 0 to 25, and from 0 to 250 milliampères, and by turning a screw at the side of the meter-case all of these scales may be brought into view successively. According to the work in hand, that particular scale is employed on which the galvanometer gives a convenient deflection. The action of the meter is automatic; so that simultaneously with a change in the scale there occurs the introduction of a *shunt* in the meter circuit, though the external circuit remains always the same.

The Waite and Bartlett Manufacturing Company have given much time to the construction and technical details of their cabinets. The illustration on page 292 shows a complete office arrangement. It contains, for use of constant current, 40 cells of Axo-Leclanché battery. The cells are the most perfect of their kind, and have stood the test of time and use, and are always furnished, unless some other form is specially desired. The current-selector is universal, and any cells, or cell, from the entire series may be used, and thus a great saving of the battery and uniform wear of same are obtained. It contains also an automatic rheotome for giving interrupted galvanic currents. The pole-changer, or commutator, is of substantial make, has rubbing

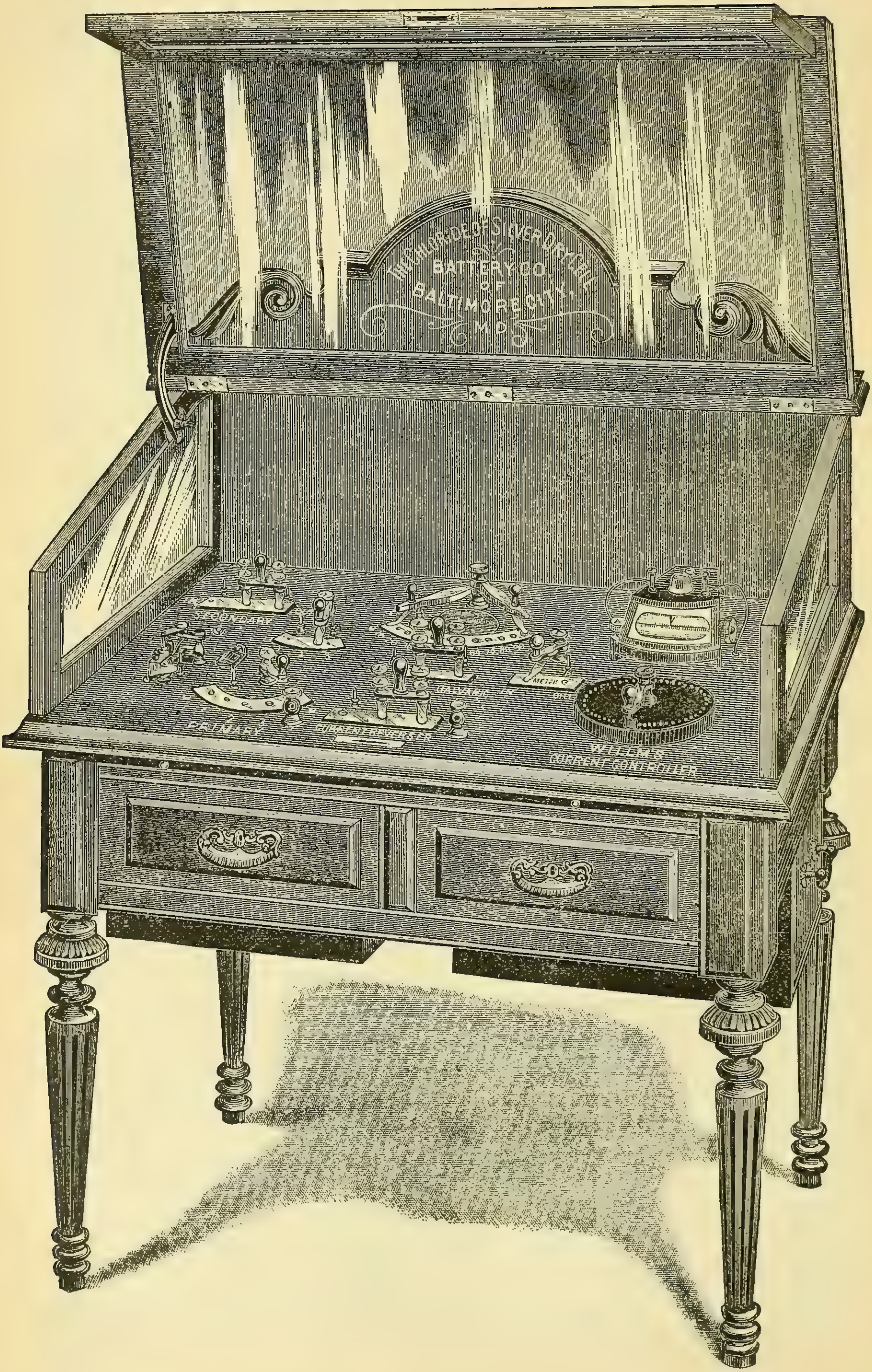


FIG. 83.—ELECTRICAL CABINET PROVIDED WITH CHLORIDE-OF-SILVER DRY CELLS.

contacts, and keeps in order. The German-silver-wire rheostat has coils from 5 ohms to 5000 ohms resistance each, the entire resistance of all the coils being 17,000 ohms, and by means of this rheostat and the milliampèremeter the resistance of the patient's body may be measured or the condition of the cells tested. The water rheostat is used to modify the current gradually. This cabinet also includes the du Bois-Reymond style of faradic apparatus. The secondary coil can be removed, and coils of various sizes and lengths of wire may be used, and the various qualities of current obtained. It is provided with a slow and rapid rheotome, also with a contact-key to be operated by the finger,—a great help in diagnosis. The instrument, also, is furnished with a reliable milliampèremeter for measuring the current-strength. The case contains two small closets with beveled-glass doors, two large drawers, and a sliding shelf available as a desk. The lower part has doors in the back as well as in the front, making the cells accessible and easy of inspection. The total height of the cabinet is 69 inches, length 41 inches, depth 22 inches.

Author's Own Appliance.—The need of an apparatus combining, both in simplicity and usefulness, all the advantages of galvanic and faradic energy led me to devise the table of which I give you an illustration (Fig. 85). The instrument is not yet on the market; it was built for me by Messrs. Waite and Bartlett, from plans and drawings furnished by myself. I have tested the apparatus in every way, and, with my long experience with the many cabinets made for the special use of electro-therapists, of which I have spoken at length in this chapter, laying aside an inventor's pride, I can frankly say that the table is encumbered with fewer disadvantages than any apparatus of its kind that I have yet seen.

It is readily understood in all its workings; and any one with even the most elementary knowledge of electro-physics can thoroughly grasp its most intimate details at a glance. Then, again, it is next nigh impossible to get the apparatus out of working-order.

On the shelves below the stand you will see 44 of the improved Gonda cells, with hard-rubber caps and paraffin coating. Of these 4 are used in the faradic and 40 cells in the galvanic current.

It is equipped, as you will observe, with the recently-devised Engelmann interrupter, by means of which it is possible to obtain from 1 to 100,000 interruptions per minute. Professor Engelmann's coils and interrupter are by far the most useful ones on the market, and the only ones constructed on exact electro-physical and physiological principles.

Only last winter Professor Engelmann, of St. Louis, and myself, assisted by my colleague, Dr. M. Milton Weill, who has devoted years to the study of electro-physiology, demonstrated the action of the interrupter and the coils before a body of the most distinguished electro-therapists in this country. At the time we showed the three distinct physiological effects produced by the interrupter at various degrees of speed.

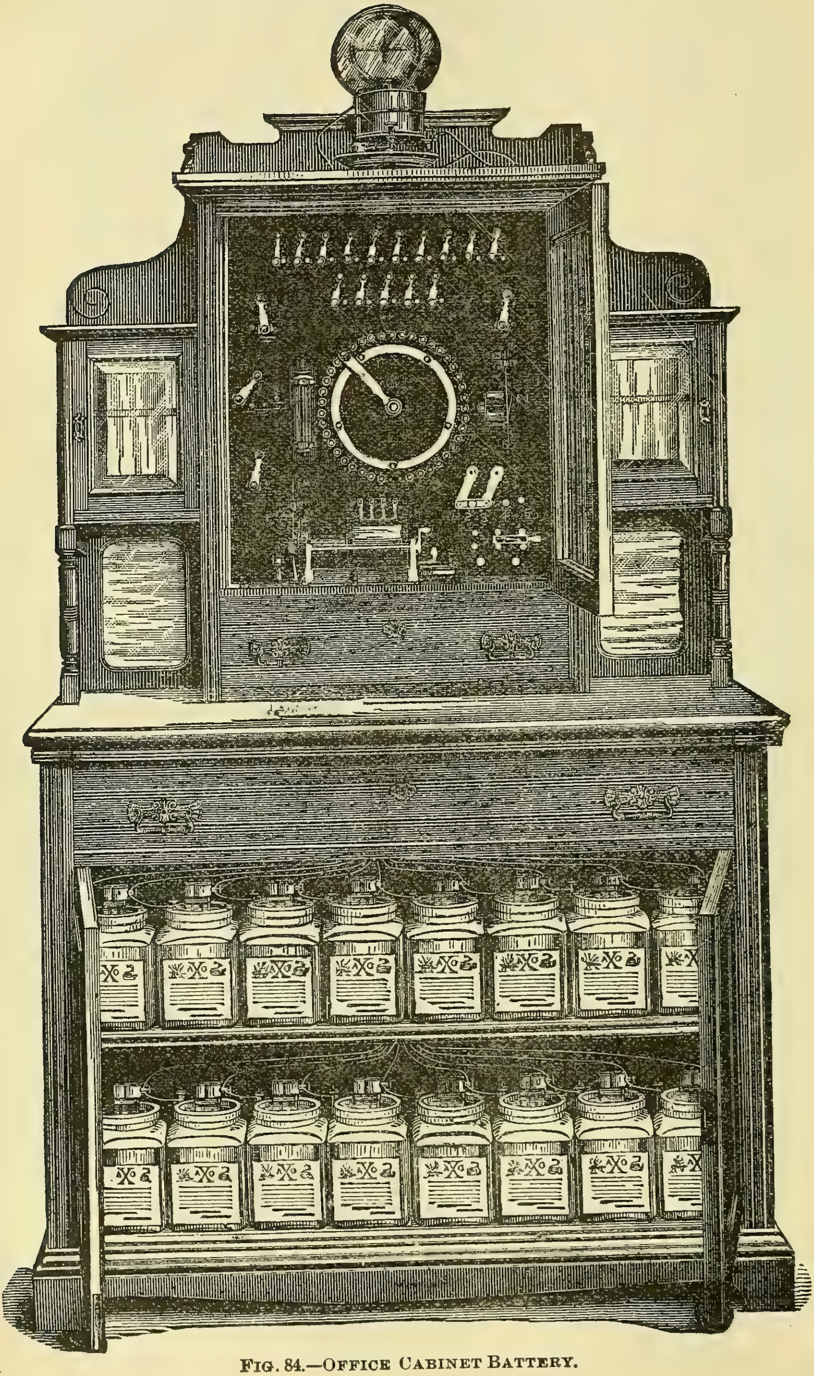


FIG. 84.—OFFICE CABINET BATTERY.

Thus, with from 1 to 6000 interruptions muscular effects alone were experienced; increasing the interruptions to 18,000 or thereabouts, the muscular responses gave place to nerve stimulation. From 20,000 breaks in the current up to 50,000 or more interruptions, the muscular and nervous effects were lost, and complete cutaneous anæsthesia of the part resulted. The large commutator and the finely-milled-edge wheel record the rate of interruptions, and the speed and number of breaks are readily read from the markings on both wheels.

As you will observe, from the experiments just recorded, we, for the

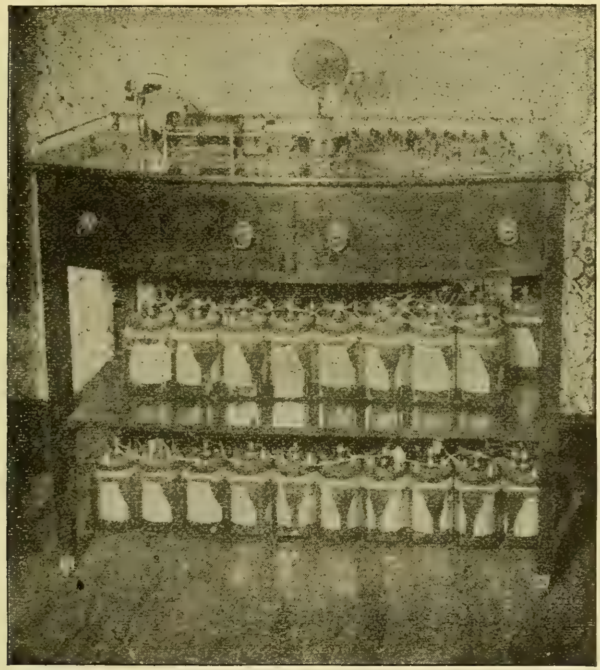


FIG. 85.

first time, find it possible to divide faradism into at least three distinct doses, and place the current under comprehensive control.

I know of no electrical appliance capable of attaining such accuracy. All the interrupters and vibrators—barring none, for I had the good fortune to make comparative tests of a dozen or more of the best ones—have a limit which in no instance exceeds 10,000 interruptions per minute. This is from accurate measurement.

A not less desirable feature of my apparatus is the fact that all the plugs and movable switches—in fact, everything governing the working of the apparatus—are before the operator, spread out upon a table, just as good as the telegrapher's switch-board and instruments are arranged.

The Engelmann coil, too, is constructed with a movable core and bobbin slide, which graduates the rise and fall of the energy of the current as to be least appreciable to the patient; and, so, violent shocks, the disadvantages of which we are aware, are avoided. In other respects the faradic division of the apparatus is built on the most accepted principles.

The galvanic current is governed from the right side of the table. Here we have the pole-changer, the mil-am-meter, and the resistance measuring apparatus, of which I will say a word in explanation. The known resistance of a dozen coils, each governed by a movable shunt, is given. Thus, if the resistance of a patient or a part, as is so essential in thoughtful treatment by means of electrical energy, is to be calculated, the part is placed into the circuit and the current as it flows through is read upon the meter. The rheostat is next thrown in, and the part or patient cut out of the circuit. The known resistance coils are then thrown into the circuit one by one, until the milliampère needle returns to the number it indicated while the patient was in the circuit. Reading off the numbers on the coils and adding them give you the resistance to an ohm. One shunt governs both the galvanic and faradic currents and, besides, the mixed current wherein one pole of the galvanic and one pole of the faradic current are thrown into circuit.

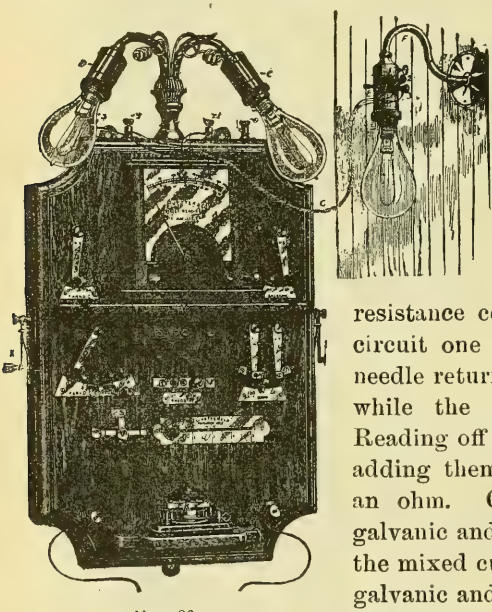


FIG. 86.

There are one or two minor attachments, such as a buzzer or bell to indicate the revolutions of the commutator wheel, which in itself is fitted with movable buckets to further place the faradic current more comprehensively under control, and other improvements which I regard as absolutely essential to a perfect electric apparatus for physicians' use. Of these I shall speak at some future day.

Stationary Apparatus Adapted for either Incandescent or Battery Current.—The above cut shows a wall or table outfit, comprising a complete combination of the latest improved Vetter instruments. An oak base, mounted with milliampèremeter, current-controller, a most complete faradic apparatus, pole-changer, switches, post, etc. This is a good electro-therapeutic outfit for galvanic and faradic and combined galvanic and faradic currents. It is adapted for either the incandescent light or current from batteries.

A very excellent wall and table plate for stationary use is the McIntosh combined semicircle one, of which an illustration is also shown. A full description and the manner of using the plate will be found in the McIntosh catalogue. If one does find room in his surgery for a cabinet, wall cabinets can be made to take the place of the more elaborate and expensive cabinets.

The Incandescent Current—Its Adaptation to the Galvanic and the Faradic, and as Regarding the Charging of Storage Batteries.—Electric light has won for itself an important position among the resources of our civilization; under the rays of science its still-unremedied defects will in time vanish. Each new improvement is gladly hailed and followed

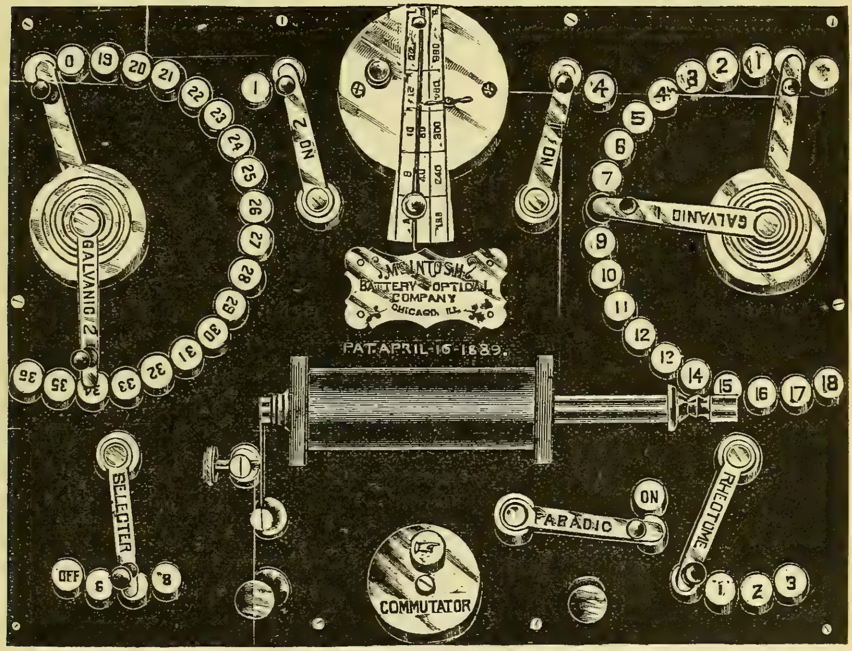


FIG. 87.—MCINTOSH WALL AND TABLE PLATE.

immediately by applications that await only the key to open up new paths, and tremendous possibilities for progressive science.

Lighting statistics show that at the present time there are, in the United States, upward of two hundred thousand arc and nearly one million incandescent lamps distributed in over seven hundred cities and towns, not less than twenty million dollars being invested in the business of electric lighting in this country alone.

We find that in medicine also the electric light has been adapted in many ways, and is, even in its present unfinished condition, invaluable in its service.

Of late, several electrical experts have given some attention to the

invention of rheostats for medical purposes, and through these electric light will come into general use among surgeons and electro-therapists. We find already that, in districts supplied with street-currents, specially-designed rheostats promise to be both useful and convenient.

The Vetter current-adapter is best suited to various purposes herein to be described, and has given, so far, the most satisfactory proof of practical application. It is simple and compact. It resembles an ordinary incandescent-lamp socket provided with a switch-lever and binding-posts numbered 1, 2, and 3. When connection is made with posts 1 and 2 it gives the current in series with the lamp, the quantity of current passing being regulated by the candle-power of the lamp. When posts 2 and 3 are used the lamp is cut out and the full force of the direct current is obtained. The switch-lever is used only for directing the current from the binding-posts to the lamp.

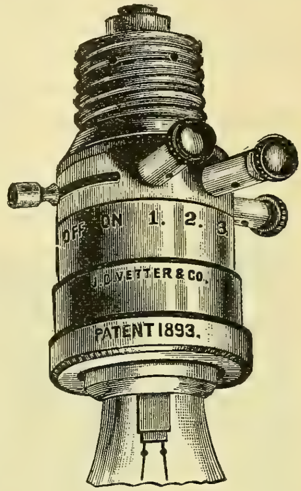


FIG. 88.

It does not require the services of an electrician to attach the adapter; any one can do it, even though not familiar with electrical appliances; it is no more trouble to attach or change the adapter from one fixture to another than it is to change a lamp; it is only necessary to detach a lamp from its fixture and place the adapter in its stead, then attach a lamp (of requisite candle-power for the purpose intended) to the adapter, in the same manner as it would be attached to the fixture.

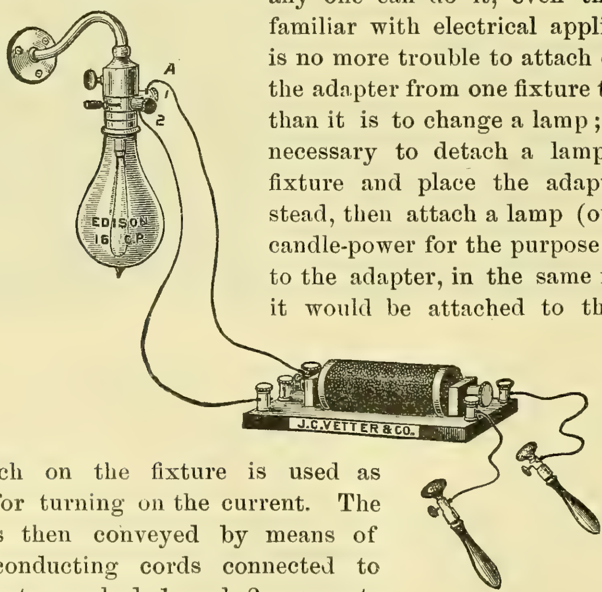


FIG. 89.

The switch on the fixture is used as formerly for turning on the current. The current is then conveyed by means of suitable conducting cords connected to binding-posts marked 1 and 2, or posts marked 2 and 3; posts 1 and 2 giving the current in series with the lamp, and posts 2 and 3 the current in parallel or direct. The switch-lever is for the purpose of lighting the lamp only.

To adapt the incandescent-light current for the operations of various translating devices requiring different ampèrage or quantity currents in their employment, it is only necessary to adjust a lamp of suitable candle-power into the adapter and, by means of conducting cords, convey the current from the binding-posts of the adapter marked 1 and 2 or 2 and 3, as shown in the illustration. (Fig. 88.)

For Faradic Current.—To obtain the faradic current directly from the incandescent current it is only necessary to adjust the Vetter current-adapter to a 16-candle-power lamp and connect posts 1 and 2 to an ordinary faradic induction coil, as shown in Fig. 89. So adjusted, it gives ½ ampère of current, or about the same amount as is given

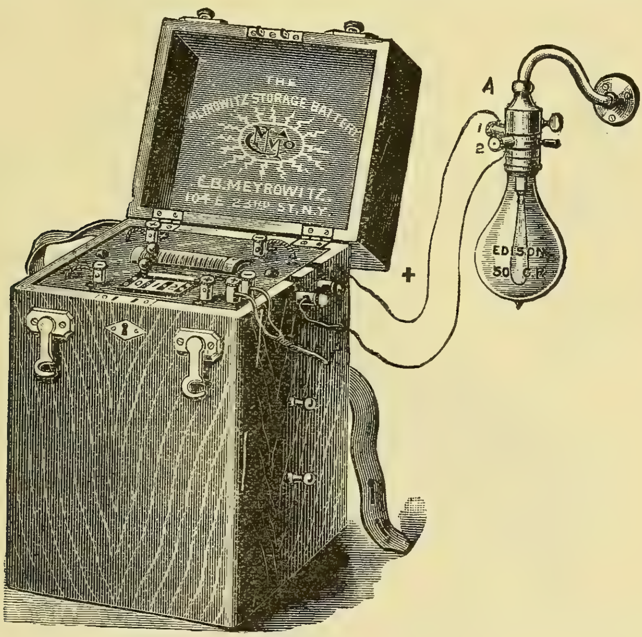


FIG. 90.

by a good battery cell. An ordinary faradic battery can be utilized in this way by connecting the cords from the adapter in place of those from the cell.

For Charging Storage Batteries.—The Vetter current-adapter furnishes a handy and clean method by which storage batteries can be easily and economically recharged, really at no expense whatever if the charging is done at a time when the lamp would ordinarily be in use, as the overflow is sufficient for the purpose. Every practitioner who has had anything to do with the uncleanly and troublesome "blue-stone cells" will understand what a relief this affords.

To recharge storage batteries a 50-candle-power lamp, giving 1½

ampères of current, would be best suited. When the current is in use in series from posts 1 and 2, the lamp in the adapter acts as resistance to the flow, allowing only a limited quantity of the current to pass in that circuit.

For Galvanic Current.—To obtain the galvanic current directly from the incandescent current by means of the current-adapter the conducting cords from posts 1 and 2 are connected to the Vetter current-controller and milliampèremeter, as shown in Fig. 91. The current-controller will in this manner control the incandescent current from 0 to 500 milliampères, which is the greatest amount the 16-candle-power lamp is able to furnish, as a heavier current would break the filament in the lamp and thus stop the current.

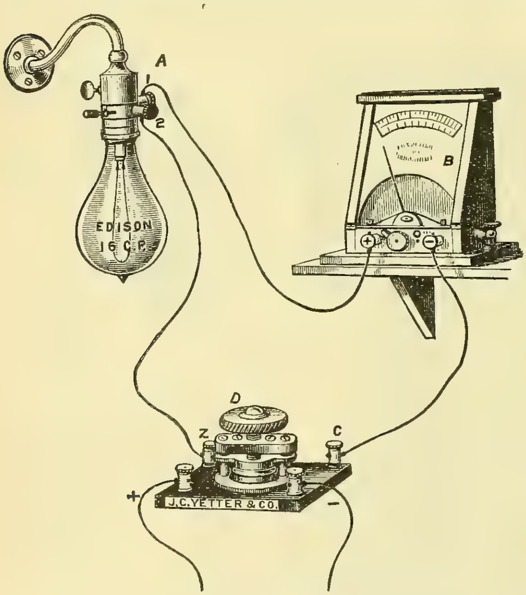


Fig. 91.

Another and perhaps the most perfect combination ever devised for obtaining the galvanic current is herewith illustrated. This illustration (Fig. 92) shows the adapter in connection with the Vetter complete, portable, dry, galvanic battery. This arrangement is especially desirable, as it furnishes the physician with the most perfect outfit for office or hospital, and at the same time a complete portable outfit for outside work. When this apparatus is in connection with the adapter the dry cells are cut out of circuit and are reserved for outside use, making an economical and convenient outfit.

Another new and excellent apparatus to be used in conjunction with the incandescent current is the Gish instrument (Fig. 93). This can be applied for purposes similar to those met by the Vetter current-adapter. This Gish instrument is designed for all galvanic and faradic work, both electro-therapeutic and diagnostic, whether it be in the hands of the general practitioner or the specialist. It also operates the small incandescent lamps used in examining the throat, nose, and internal cavities of the body and electro-magnet. A very important point in using galvanism from this rheostat is that the patients can be treated without giving them any shock whatever, and this one advantage in certain nervous dis-

eases is pre-eminent. Also, the graduation is so fine that the current can be started from zero and give any number or fractional part of milliampères that is required.

There is another form of the Gish instrument (Fig. 94) which is designed for the electro-cautery, and will heat all knives, from the smallest point such as is used in cauterizing corneal ulcers to any electrode requiring 18 ampères of current, and heats the platinum cautery snare. It illuminates incandescent lamps from $3\frac{1}{2}$ volts candle-power upward to the full extent of the current. It also operates the 5-volt motors, adapted

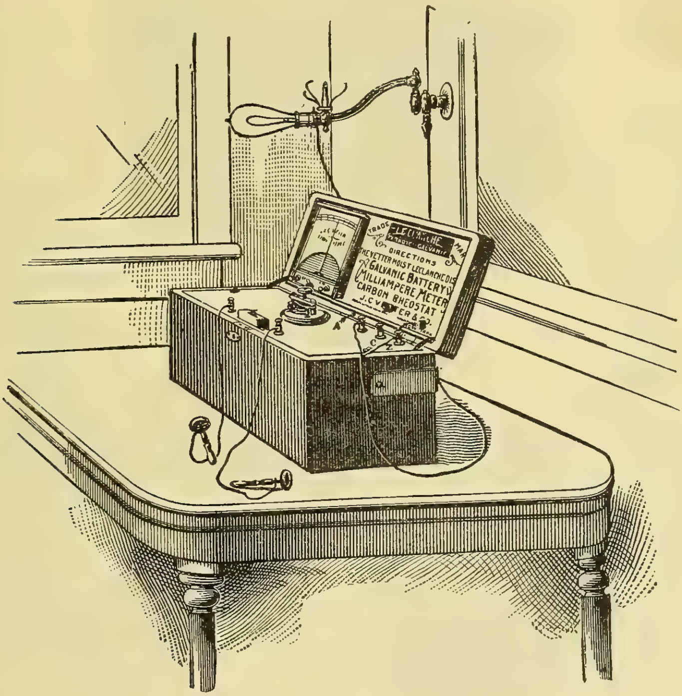


FIG. 92.

to storage batteries, at any desired speed without variation. Special directions accompany each instrument.

McIntosh has lately brought out also an apparatus for use in connection with the incandescent electric light, which is shown in Fig. 95, and a description is given of the mode of operating the same. In order to use this contrivance the following points must be adhered to rigidly :—

Connect the two wires at left side of plate to any Edison current of 120 volts. Be sure and join the wire with knot in it to the *P* of line.

To Get a Galvanic Current at Binding-Posts.—Turn on snap switch in centre of board. Put plug in hole near right-hand lamp and see that the fuse-wire near left-hand lamp is not broken. Fill rheostat bottle with

pure water to within one-half inch of neck part of bottle; place plates in carefully and lower the centre plate with milled screw. Put rheostat switch on the on-button near milliampèremeter and milliampèremeter switch on *A*. Then with cords and suitable electrodes from binding-posts put patient in circuit, lowering your rheostat plate, and watch mil-

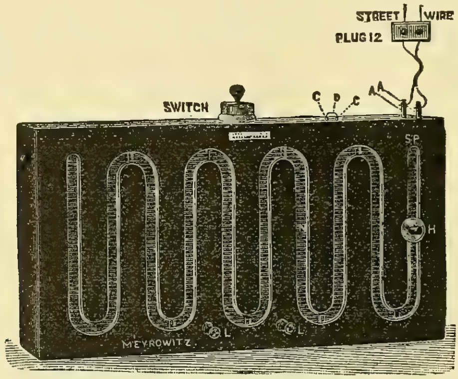


FIG. 93.

liampèremeter until you get the proper strength of current. If you wish to reduce this current still more, turn on the 50-candle-power lamp at right-hand side of board, which is in a shunt circuit with the other lamp. The current at binding-posts on a short circuit with left-hand lamp only is 102 volts and $\frac{2}{5}$ ampère. Now open the 50-candle-power lamp and you

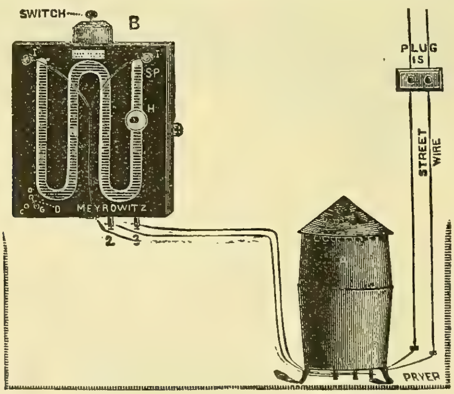


FIG. 94.

get 29 volts and $\frac{7}{20}$ ampère (providing you connect board to Edison main of 120 volts).

To Get a Faradic Current.—Open 50-candle-power lamp. Turn faradic switch near coil on the on-button. Put selector switch on *P* (primary) or *S* (secondary). Place milliampèremeter switch on off.

Keep rheostat switch on the on-button. Touch vibrator on coil to cause it to start and regulate your current with rheostat.

Note.—After through using board turn off snap switch and take out plug near right-hand lamp. Before using turn on snap switch, see that safety switch is not broken, and place in hole the plug cut-out. If the plug cut-out is carried on the person it will insure against children or others meddling with the board.

Caution.—Never use the board without the safety-fuse being in

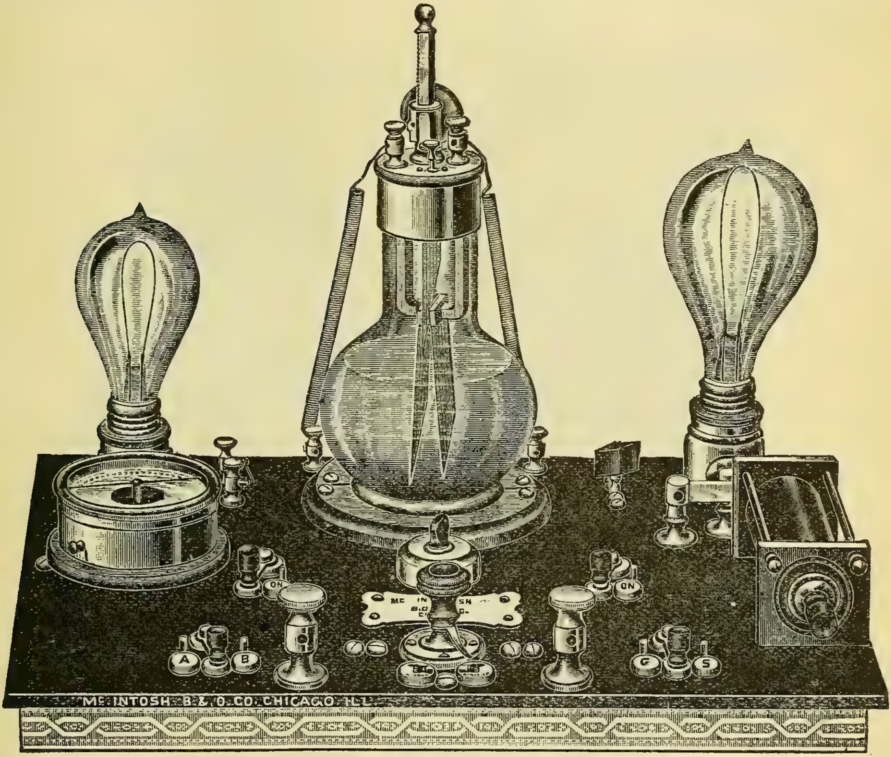


FIG. 95.—THE McINTOSH ELECTRIC-LIGHT SWITCH-BOARD.

place; in case of accident by short circuit or otherwise this safety-fuse will be burned out, and so break the circuit.

There are several other rheostats made by electric-lighting companies, but none so practical for the novice as the ones described. The lighting problem, however, involves many considerations that demand investigation before electric light can become altogether practicable; but we believe that not one of these questions is insoluble, and we hope before long to witness at least a partial transformation in general illumination with the many now possible uses of electricity.

GALVANO-CAUSTIC APPARATUS.

We shall give a description of several batteries which are of great service in particular branches of the medical science, viz., in cauterizing by electricity. For this purpose a heated platinum-wire loop or flat pieces of platinum suffice for cautery knives, loops, etc. Bleeding is almost entirely prevented, and parts most difficult to reach can be operated on, as the heat is more local. Formerly a red-hot iron had to be introduced into the part to be cauterized, but now the platinum wire is inserted while cold, and is made white-hot, or according to the will of the operator, by simply making contact.

Much has been done to advance this branch of medical science by

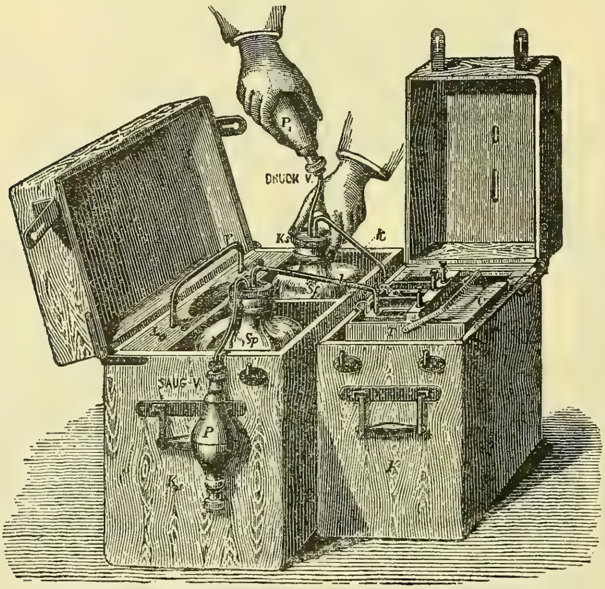


FIG. 96.—LEITER'S GALVANO-CAUTERY.

A. Middeldorf, Recámier and Pravatz, Steinheil, Heider, and others. It will be seen that, as the outer circuit of these batteries is a platinum loop which has only small resistance, it is advantageous to have the inner resistance of the battery also only slight. Hence the battery used has large plates and few elements,—that is to say, the elements are joined up for quantity.

An apparatus constructed by Leiter, of Vienna, for the purpose, is shown in Fig. 96. In its essential parts it is a modified Bunsen battery. The box K contains the battery, and the box K_1 the two acids (sulphuric and nitric). The battery-vessel, T, consists of gutta-percha, and is divided into two portions. In each of these a flat earthenware cell is placed to hold the carbon plate and nitric acid. Outside this dia-

phragm come the zinc plate and dilute sulphuric acid. The elements are covered by means of a gutta-percha lid. The pole-clamps of the battery are screwed to the lid. When only one element is required, clamps 1 and 2 are used; when both elements are required, clamps 1 and 3 are used. The *Sf* is being forced through the bent-glass tube, *K*, by means of the India-rubber balls, *P* and P_1. The acid is removed from the cells by exhausting the acid bottles, and a longer bent-glass tube will then have to dip into the cell. Another form of Leiter's cautery battery is seen in Fig. 97.

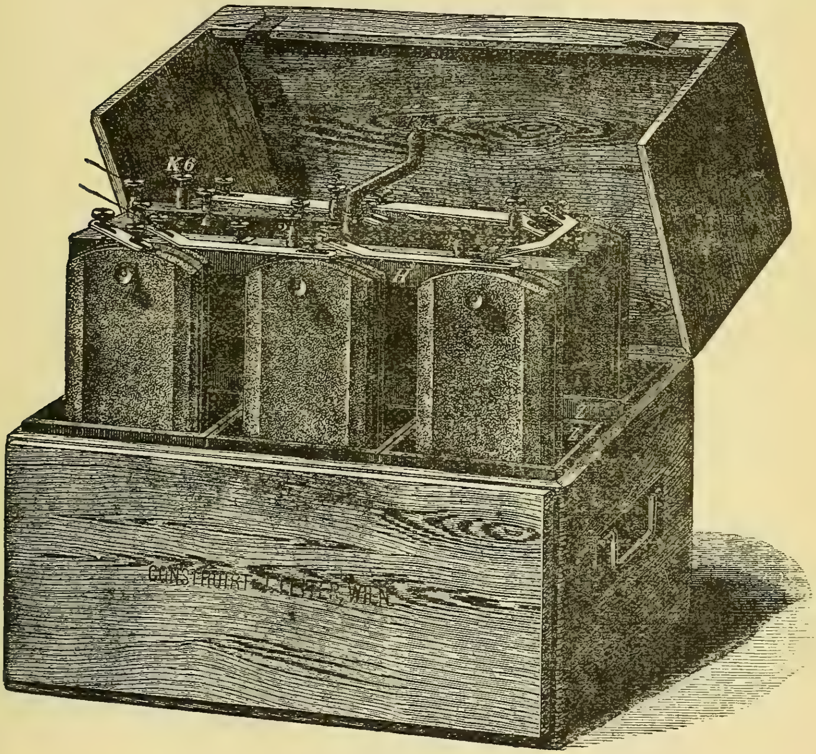


FIG. 97.

We shall also consider the Gibson storage cell, manufactured by W. E. Ford, of New York. A cut of the small portable cautery is shown (Fig. 98). It is put up in hard-rubber or glass jars, with a screw-top cover, hermetically sealed so that the acid cannot spill out, and is inclosed in a polished hard-wood case holding either one or two cells and a rheostat, and is best adapted to take out to an operation. He also makes other types of cells, which are best adapted to stationary use. Any one of the cells has sufficient power to heat a small cautery knife. Any two of these cells will heat the largest-size knife or loop,

and will light a small lamp. The only difference in the cells is the length of ampère hours they will run, they all having the same electro-motive force.

In my discussion on batteries I have spoken of the Edison-Lalande cell *in extenso*, but I must say a few words regarding these cells for cautery purposes. There are many of them at present in use in the best offices and institutions throughout the United States. This cell has now

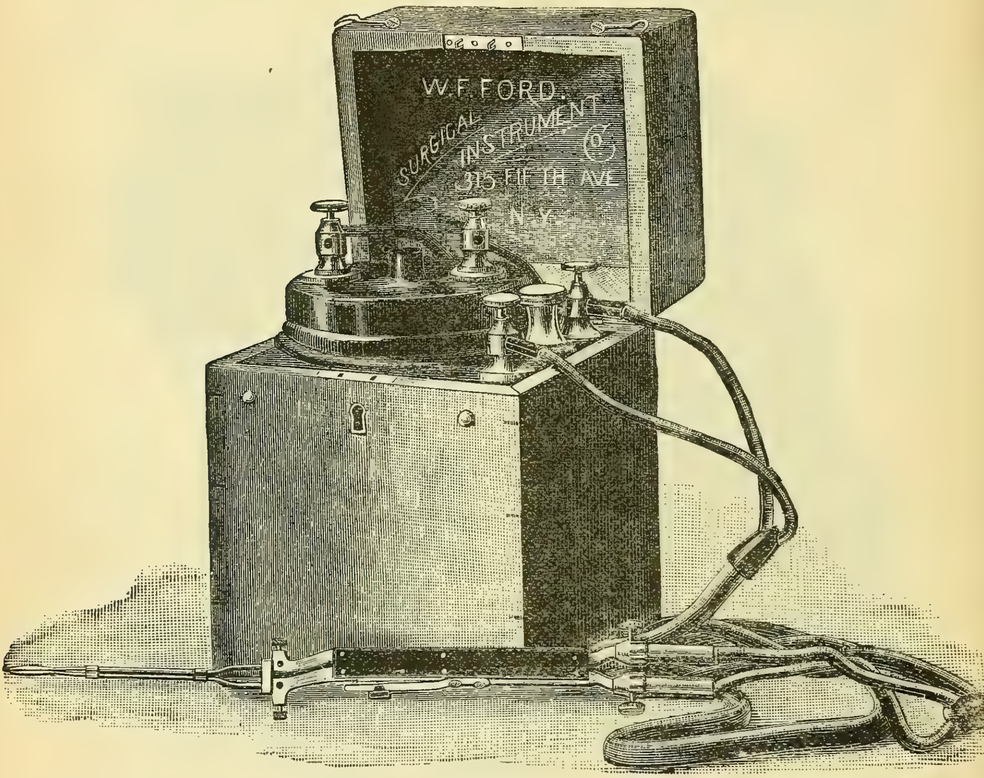


FIG. 98.

been brought out by the Edison Manufacturing Company, in a form that renders it peculiarly efficient.

Eight of these cells, each in a rubber case, are placed in an oak box and connected in series by means of nickel-plated straps. The resistance is included in the outfit, and is placed in a very novel manner in the top of the case, on a little hinged lid that can be thrown up so as to expose all the batteries clearly to view. This resistance is in the shape of metallic tape, and operates after the manner of a fishing-reel or ordinary yard-measure. It is pulled out to any length as required, and when the needed resistance is obtained is held at that point. As the

battery falls off, it can be released and rolled up automatically either all at once or gradually.

As is well known, the usual cautery knife requires a considerable volume of current to keep it at white heat—say, 15 or 20 ampères. Of course, in practice the cautery knife is used only a few seconds at a time; the battery therefore would have, with a single charge, a very long life. But, if for any reason it should become necessary to use the knife for an extended period, it may be kept at white heat for eight hours with a

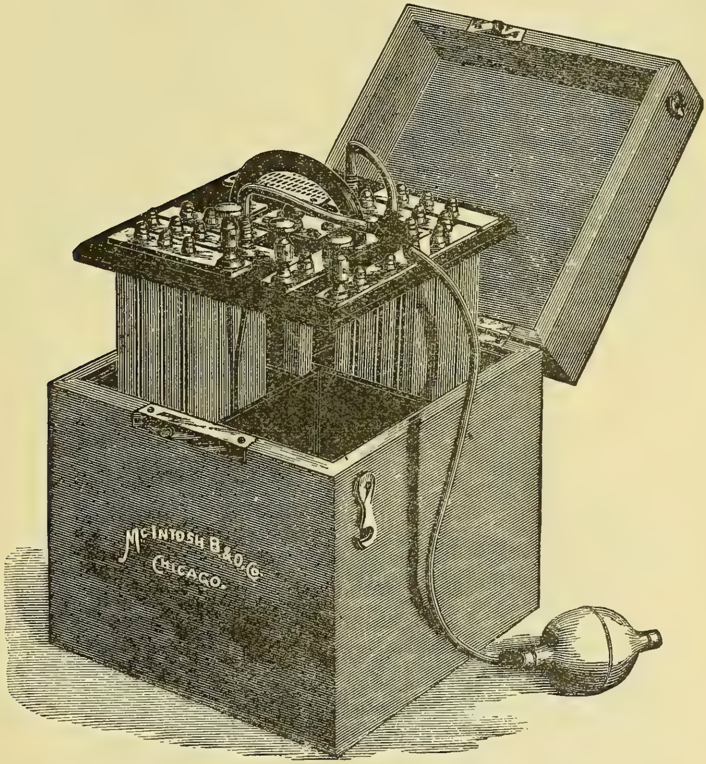


FIG. 99.—MCINTOSH PORTABLE GALVANO-CAUTERY.

single charge, and there will be sufficient current to maintain the ordinary snare at proper heat for many hours.

The McIntosh galvanic cautery is also much in use by many practitioners. This battery is designed expressly for cautery work. It is inclosed in a polished black-walnut case eight and one-half inches long, eight and one-half inches wide, and ten and one-half inches high, and weighs twenty-one pounds. The elements are composed of zinc and platinum, fastened upon a hard-rubber base. They are constructed so as to furnish a very large surface in the smallest possible space, thereby lessening the resistance and increasing the power of the battery. The

cells and drip-cups are made of hard rubber. The base and elements can be fastened at any height by a spring-bolt that slips into slots in a central upright metallic tube; by this means the current can be graduated to any required intensity. This battery is very compact, portable, and can be easily managed by any physician. It is adapted to all cases where galvano-cautery is applicable. (Fig. 99.)

Some of the well-known galvano-cauteries of foreign make are those of Trouvé, of Paris; Mayer and Meltzer, of London; Down Brothers, of London, and Coxeter & Son, London. Besides the galvano-cautery battery in surgery, the Gramm machine was enlisted also into its service. Dr. Hedinger, of Germany, was the first to put it into practice. It is so constructed that it can be run either by hand or motor power. This is a very valuable cautery for stationary purposes and where motor power

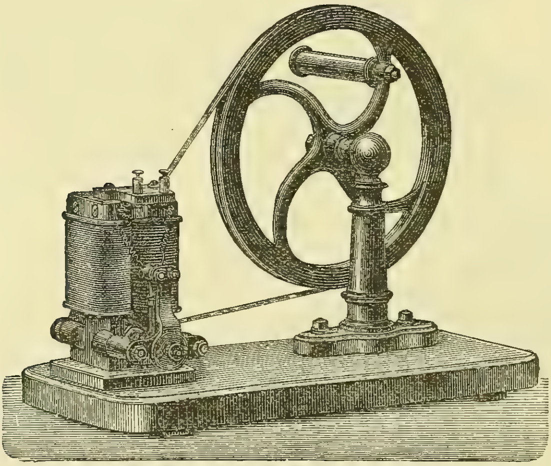


FIG. 100.—THE GRAMM MACHINE FOR CAUTERY USE.

can be had. A description of this Gramm cautery is hardly necessary, as the cut fully describes the machine.

There are other primary and secondary batteries, but the limited space allotted, in a work of this order, does not permit me to dilate further. I have already mentioned other methods of using the cautery, as by the incandescent-light tap and by rheostats.

PORTABLE BATTERIES FOR ELECTRIC LIGHTING.

The science of medicine owes much to the artificial sources of light for means of examining such portions of the body as cannot be directly seen. As instances we may mention the larynx-mirror used by Liston in 1840 and re-introduced by Czermak in 1858, and the eye-mirror with the help of which Helmholtz obtained for the first time a light of the structure of the living eye, etc. As a rule, daylight or a lamp is used

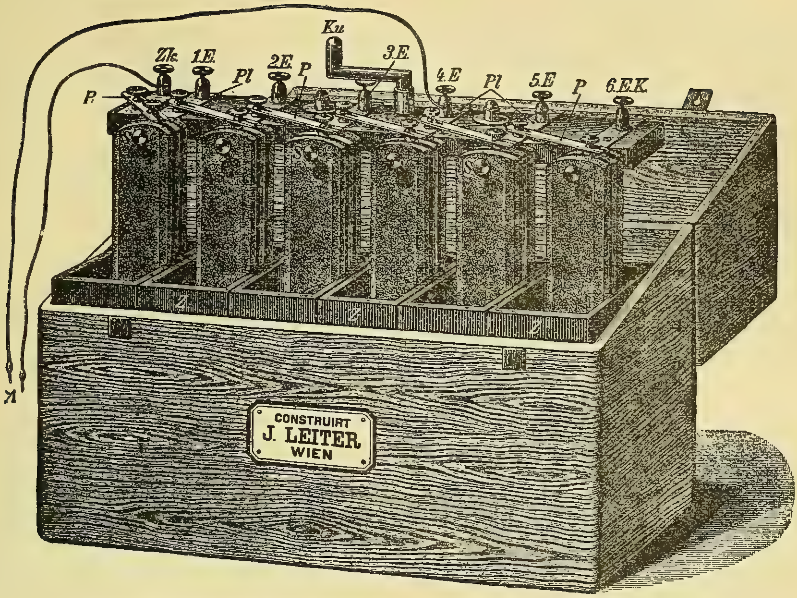


FIG. 101.—LEITER'S PORTABLE LIGHTING BATTERY. (Large size.)

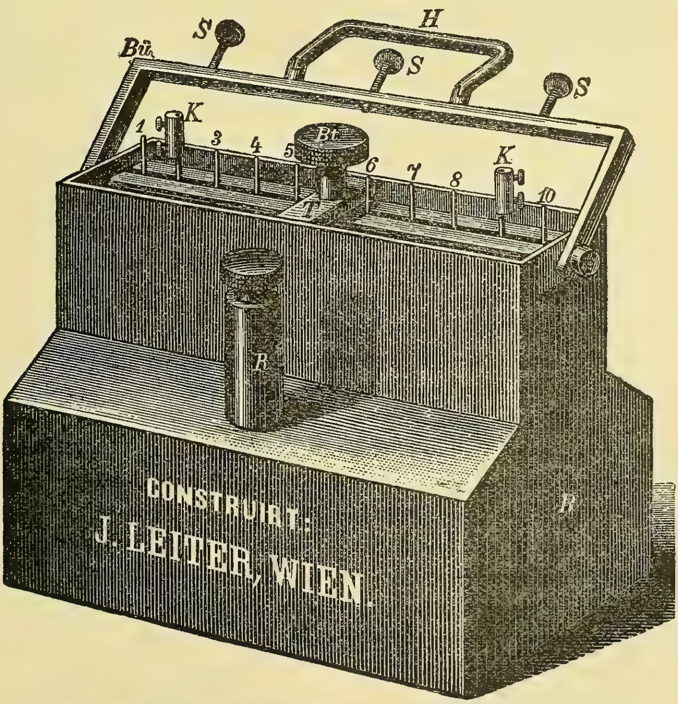


FIG. 102.—LEITER'S PORTABLE LIGHTING BATTERY. (Small size.)

for such examinations, the rays being concentrated by means of a concave mirror; but, as we shall show, the use of a glow light in such cases is extending. A second method in making the body under examination visible is to introduce the source of light itself, and for this purpose the electric light alone can be used.

There are instruments constructed by various surgical manufacturers throughout the world for all kinds of illumination,—within and for without the body. Amongst the first manufacturers is J. Leiter, of Vienna. The different illuminating instruments will be touched upon by my co-editors in their special branches. I only wish to speak upon the portable batteries for illumination. Two of the Leiter portable batteries are shown on preceding page.

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ELECTRO-PHYSIOLOGY.

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Historical Introduction.

One of the most interesting chapters in the history of physiological science is that relating to the origin and development of the electrical phenomena of muscles and nerves. Here, if anywhere, we have a striking illustration of the fact that new discoveries are not always the result of logical thought and a correct interpretation of phenomena. On the contrary, the history of electro-physiology clearly shows that often the new discoveries were dependent upon faulty observations, imperfect deductions, and bitter controversies; for, had Galvani's explanation of the first observed contraction been the correct one, it is quite possible that the phenomenon would have aroused but slight interest, and the development of electricity and physiology would have been retarded for many years.

Luigi Galvani, a professor of anatomy and physiology in Bologna, while making some experiments with a frictional apparatus, had his attention drawn to the fact that a recently-dissected frog's leg was thrown into a violent contraction whenever it was touched with a scalpel held in the hand of his assistant. Further investigations revealed, moreover, that the contractions occurred only when a spark was emitted from the frictional machine, and then only when the metallic substance was in contact with the preparation. Galvani was unable to offer any explanation of this phenomenon, as there was apparently no connection between the electrical machine and the frog's leg, by which the electrical spark could be conducted. The exact time of this observation is not known, but it is quite certain, from the evidence gathered by Prof. du Bois-Reymond ("Untersuchungen über thierische Electricität," Bd. i, S. 31), that it was prior to the year 1786, the date usually given in text-books. It is quite probable, from notes and dates upon the margins of his manuscripts, that Galvani began his investigations as far back as November, 1780. From this period he continued his observations and experiments up to the year 1786, when it occurred to him to determine whether the effects of atmospheric electricity upon the frog's muscles would be the same as that from the frictional apparatus. This supposition was confirmed by a series of experiments made during the year 1786, from the 26th of April to the 17th of August, for every flash of lightning was immediately followed by a contraction of the muscles. While yet occupied with these investigations, another observation was accident-

ally made by Galvani, which became the real starting-point for the development of the new science of electricity; for hitherto his observations had disclosed no new principle, although Galvani himself believed that only a new principle—animal electricity—could account for the phenomena. The effect of the electrical returning-stroke, however, which had been described by Lord Mahon, in 1779, in his "Principles of Electricity," offers, indeed, and was so held by Volta, a sufficient explanation for all the phenomena so far observed. On the evening of September 20, 1786, Galvani prepared and suspended three frogs to the iron trellis-work of his house by means of iron and, subsequently, of copper hooks, and observed that whenever the wind brought them into contact with the iron violent contractions took place. These movements Galvani also, at first, attributed to atmospheric electricity; but when it was afterward observed that the same phenomena occurred independently of variations in the electrical conditions of the atmosphere, and even in closed rooms, he arrived at the conclusion that the metallic arc, composed of either similar or dissimilar metals, was one of the conditions necessary for the production of contractions. That Galvani had, therefore, a true but slight perception of the cause of the contractions in these experiments is evident from the title of his paper, "Esperimenta circa l'Elettricita di metalli." He soon abandoned this view, however, and, from many other experiments, arrived at the conclusion that the electricity was developed within the animal tissues themselves, and that the metallic arc merely conducted the electricity from one part to another. These observations and conclusions were published in 1791, in the celebrated "De viribus Electricitatis in motu musculari commentarius."

With the publication of this paper, the attention of the whole scientific world was directed to Galvani's experiments. They were repeated again and again, wherever frogs were to be found and dissimilar metals procured, by all those who wished to familiarize themselves with these remarkable phenomena. Among the many distinguished men who became interested in this subject there was one who, by a series of delicate electrical experiments with Wilcke's electrophorus and the condenser, had made himself a recognized master in the field of electricity. Alexander Volta, a physicist, and professor of natural philosophy in the University of Pavia, repeated Galvani's experiments, and at first entered fully into the views of his countryman. But his calm and philosophic mind soon observed the important part which the arc played in the production of contractions; for, as he was unable to excite contractions except by a combination of heterogeneous metals, he soon dissented from the interpretation of Galvani, although the latter had already perceived and stated that the contractions were stronger when the arc consisted of two dissimilar metals than when composed of a single homogeneous metal. Volta then endeavored to produce muscular contractions in the tongue by placing on its upper surface a layer of tin-foil and on its under surface a

silver spoon. When the circuit was closed, to his astonishment, he experienced, instead of the expected muscular contraction, a strange sensation of taste, and perceived that this sensation persisted as long as the two metals were in contact with each other and the two surfaces of the tongue. This experiment had been made by Sulzer in 1754, and recorded simply as a curious fact; but to Volta's mind it became a potent argument for his view, that the electricity which produced the contractions was not resident in the animal tissues, but was developed by the contact of two dissimilar metals with moist tissues. Subsequently he proved by physical apparatus that electricity was developed by the contact of two dissimilar metals with a moist conductor, independent of any animal tissue. Sulzer's experiment thus gave birth to voltaic electricity, the greatest discovery of the eighteenth century.

In support of his position Galvani asserted, and apparently demonstrated, that it was possible to excite contractions, though perhaps feeble ones, by contact of homogeneous metals; but Volta replied that, when metals were believed to be perfectly homogeneous, there were on their surfaces slight differences in temperature, hardness, polish, etc., which were sufficient to produce the electricity. Galvani then employed mercury as a metallic conductor, to which he thought the objections of Volta could not apply; by dipping the limb into the mercurial trough contractions at once resulted. To this experiment Volta replied that the surface of mercury was wanting in perfect homogeneity from the contact of air and moisture, and, therefore, capable of developing electricity.

Galvani's position thus seemed to be completely controverted by these experiments. It now remained for him to show that contractions could be produced without the contact of metals at all, and, in 1793, he offered what he believed to be the *experimentum crucis* in support of his theory, and which would establish it upon a firm and enduring basis. The leg of the frog was denuded and the sciatic nerve dissected out and its upper end cut off close to the spine; then, by means of non-conductors and without subjecting the nerve to any influence which could produce change in it, he gently brought its cut end in contact with the muscle. At once a distinct pulsation ensued. Similar pulsations were caused by allowing the nerve to fall upon a piece of abdominal muscle which was lying on a glass plate, and which had no connection with the frog. Galvani had thus apparently proved his case. Volta, however, did not admit his conclusions, and endeavored to refute them by declaring that the contractions so caused were extremely weak in comparison with those caused by the contact of heterogeneous metals, and that they were due to mechanical irritations incidental to the manipulations of the nerve. Subsequently he retracted these statements, and offered as an explanation that the electricity in these experiments was developed from contact of dissimilar fluids and tissues: a view which was readily accepted,

as even Galvani and his followers had recognized that, after the contractions had become feeble or had entirely ceased, it was only necessary to moisten the muscle and nerve with blood, saliva, or some alkaline or acid fluid to again excite contractions. Thus again did Volta's marvelous dexterity convert Galvani's victory into an apparent defeat.

From this brief sketch of the long controversy between these two distinguished investigators, it is clear that the assertions of both are correct in many respects, and their denials equally incorrect. In all these experiments Galvani maintained the presence of electricity in animal tissues, but denied its development by the contact of metals; Volta maintained that the electricity was only of metallic origin, and denied its existence in the animal tissues.

In the next few years Galvani tried repeatedly, but unsuccessfully, to refute his great antagonist; even Alexander von Humboldt's remarkable experiments, in which all the extraneous influences objected to by Volta were carefully avoided, were of no avail. Humboldt recognized and stated the true position in the following words: "It is indisputably true, and first demonstrated by the observations of the great Ticinian philosopher, that when animals are not convulsed by homogeneous metals they will be so affected when the metals are made heterogeneous by the slightest change in their composition, polish, hardness, form, or temperature. This is the result, it appears to me, of Volta's experiments, and not that muscular contractions can only occur when the metals are heterogeneous."

Owing, however, to Volta's growing influence, Galvani's theory began to lose its adherents. Galvani himself died on December 4, 1798; happily for him, as, in the succeeding year, Volta discovered the pile, which enabled him to triumph over his adversary and to cause almost a total destruction of his theory. For the space of twenty-seven years animal electricity was almost lost sight of, although a few distinguished men, like Humboldt, Erman, and Pfaff, defended it, and Johannes Müller admitted its possibility. Voltaism developed from year to year, and by its aid brilliant discoveries were made in chemistry and physics, foreshadowing the great electrical discoveries and appliances of the present day. Nevertheless, it was this highly-developed voltaism which was destined to show the error in Volta's denial of the existence of animal electricity, though he himself did not live to witness the refutation of his erroneous statements.

In 1820, six years before Volta's death, the Danish philosopher, Oersted, discovered electro-magnetism. He found that an electric current, passing above or below a magnetic needle, immediately deflected it from the meridian. This discovery, in the hands of Schweigger and Poggendorff, led to the construction of the sensitive multiplicator, which in 1825 was rendered still more sensitive by the addition by Nobili of Ampère's astatic needles. By thus giving birth to this delicate and refined

apparatus, "metallic electricity," in the words of du Bois-Reymond, "was to atone for the wrong she had done to her more delicate twin sister, animal electricity, in their earlier years."

After the lapse of twenty-eight years, Nobili was the first to again take up the subject of animal electricity in a scientific spirit. The first use he made of his galvanometer was to seek for the electrical currents in muscles and nerves,—in which, however, he was unsuccessful. The method he adopted was as follows: The spinal column and feet of the frog were dipped into two vessels containing a solution of salt and the multiplicator included in the circuit. As soon as it was closed the limbs were convulsed, but the needle remained stationary. With a new and more sensitive multiplicator, Nobili was enabled to obtain a deflection of twenty and even thirty degrees, and always in a direction which indicated the passage of a current, in the frog, from the feet to the head. This current he called "la corrente propria de la rana," which, later, du Bois-Reymond termed the "frog-current." Of this current, Nobili demonstrated that it is not only present at the moment of closure, but that it is constant, and that its power increases with the number of frogs employed. While he thus discovered the existence of the frog-current, he was led into the error of supposing it was independent of physiological processes, and thermo-electric in origin,—an opinion which was also shared by de la Rive and Magendie.

A few years later, Carlo Matteucci began his investigations in the field of electro-physiology. He started with the endeavor to bring all physiological phenomena into some connection with electrical forces, which necessarily vitiated many of his conclusions and experiments. Nevertheless, he was the first to show, in 1838, by a series of experiments, that the electro-motive action upon which the frog-current depends is independent of the contact of nerve and muscle; that it is not necessary to prepare the frog according to Galvani's method, but that it sufficed to connect any two points of the frog's body—the back and leg, for example—to obtain a marked deflection of the needle. In 1841 he formulated the following law: The interior of a muscle, placed in connection with any part whatever of the same animal, such as nerve, surface of muscle, skin, etc., produces a current which goes, in the animal, from the muscular part to that which is not so.

In the spring of 1841, Emil du Bois-Reymond, at the suggestion of Johannes Müller, repeated and extended Matteucci's experiments contained in his "Essai sur les phénomenes électriques des animaux" (Paris, 1840). This investigator soon discovered the fact that all muscles and nerves are the seats of electrical currents, which differ in intensity and direction, and that the frog-current is but the resultant of individual currents, whose direction from the foot to the head is merely accidental and not essential. The first results of his investigations were embodied in his paper entitled "Vorläufiger Abriss einer Untersuchung über den

sogenanaten Froschstrom und über die electromotorischen Fische," published in Poggendorff's *Annalen der Physik und Chemie*, January, 1842. With the aid of improved galvanometers, and various forms of apparatus devised by himself, du Bois-Reymond was enabled to accurately determine and formulate the laws relating to the electrical phenomena of muscles and nerves. The result of these laborious investigations was published in his great work, "Untersuchungen über thierische Electricität," 1848, from which year it may be said that electrophysiology took rank as a distinct science.

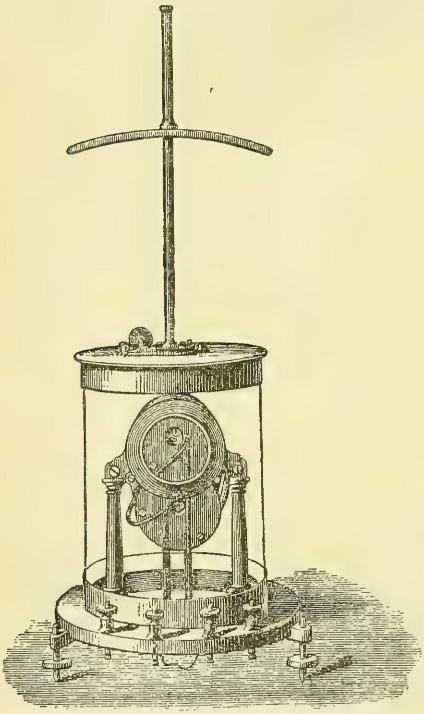

FIG. 1.—THOMPSON'S GALVANOMETER.

METHODS OF INVESTIGATION.

Galvanometer.—In the investigation of the electrical currents of muscles and nerves the physiologist is limited practically to the galvanometer, though in recent years the capillary electrometer has afforded valuable assistance. The essential requisites of any galvanometer used for physiological purposes are that it possesses a high degree of sensitiveness, responding quickly to the influence of extremely-weak currents. These conditions have been realized by the use of small, light needles; the adoption of the astatic system, as suggested by Ampère and Nobili, by which the directive influence of the earth's magnetism is eliminated; and multiplication of the number of turns of the wire by which the needles are surrounded; this latter arrangement, within certain limits, increases the effect of feeble currents with which we have to deal upon the needle. One of the best galvanometers is that of Sir Wm. Thompson (Fig. 1). The principle upon which this instrument is constructed is the same as that of the ordinary galvanometer. Its superiority as an apparatus for refined physiological research lies in the fact that the needles, of which there are two sets, an upper and a lower, are very small and light, not measuring more than an eighth of an inch in length. They are united by a rod of aluminium and arranged astatically. To the upper set of needles there is attached a small, slightly-concave mirror, about six millimetres in diameter. The system of needles and mirrors, so slight and delicate that it hardly weighs more than a grain, is

suspended by a single fibre of silk from the vulcanite frame of the wire coil. Around each set of needles is arranged a coil of fine wire, the upper of which is wound in a direction opposite to that of the lower coil. The terminals of these wires are attached to four binding-screws on the vulcanite disk. The coils are supported by brass uprights, covered by a glass shade, brass bound, which rests upon the vulcanite base, the whole being leveled by three screws. From the centre of the brass disk covering this shade rises a brass rod which carries a movable, curved magnet, slightly magnetized, by which it is possible, by moving it up and down, not only to neutralize the earth's magnetism, but to create an artificial meridian in any direction. For observing the deflections of the needles, a lamp and scale arrangement, such as shown in Figs. 2 and 3, is used, which is placed about three feet from the galvanometer. A small slit in the frame beneath the scale permits a narrow beam of light to pass to the mirror and by it is reflected to the scale. The image is brought to the zero-point by shifting the position of the magnet by fine adjusting-screws. When the

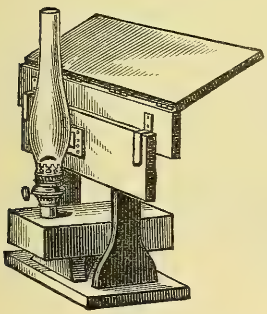

FIG. 2.

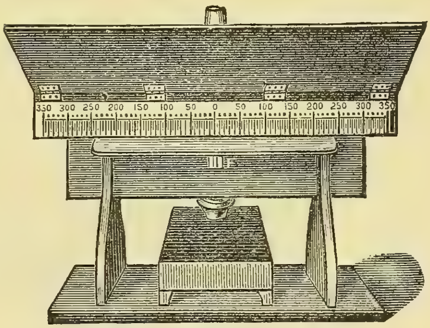

FIG. 3.

electrodes are connected with the two outer of the four binding-screws, and the two inner ones joined together, the current to be investigated will pass through both coils; by removing the connecting wire between the two inner screws, the instrument may be converted into a differential galvanometer, and the relative intensities of two currents easily determined. The particular galvanometer which is used in the physiological laboratory of the Jefferson Medical College has a resistance of 6821 ohms at a temperature of 18° C. A single Daniell element produces through a circuit of 204,660,000 ohms resistance a deflection of 180 degrees on the scale, or a deflection of 1 division through a circuit of 36,838,800,000 ohms resistance. Owing to the extreme delicacy of this instrument it is provided with a shunt, by means of which a fractional part only of the current to be investigated is permitted to pass into the galvanometer. The coils of wire of which the shunt is composed are of varying lengths, and so arranged that they can be united by brass plugs. The resistance of the coils is so graduated, with reference to the resistance of the galva-

nometer, that it is possible to permit $\frac{1}{10}$, $\frac{1}{100}$, or $\frac{1}{1000}$ of the total current to influence the needle.

The tangent galvanometer, or *boussole*, as constructed by Wiedemann, is the form most generally employed in physiological investigations (Fig. 4). It consists primarily of a thick copper cylinder, through which a tunnel has been bored. Within this tunnel is suspended a magnetized ring, just large enough to swing clear of the sides of the chamber. The object of making the magnet ring-shaped is to increase its strength in proportion to its size, and to get rid of the central inactive part. Connected with and passing upward from the magnetized ring through the copper cylinder is an aluminium rod, surmounted by a circular plane mirror. Above the mirror rises a glass tube, which carries on top, on an ebonite support a little windlass, capable of being

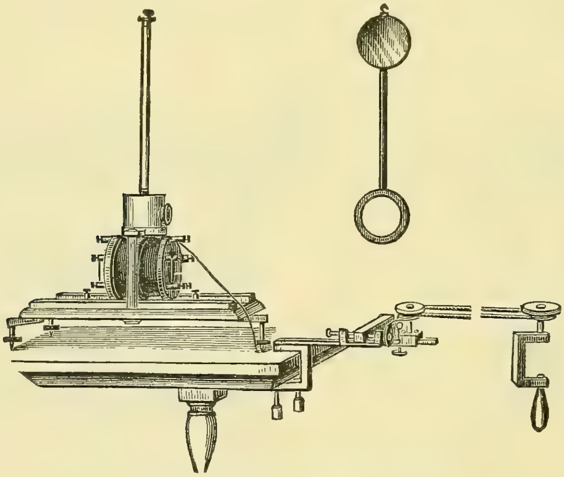

FIG. 4.—WIEDEMANN'S BOUSSOLE.

centred by three small screws. On the windlass is wound a single filament of silk, which passes down the tube and is attached to the mirror. The magnet can, by this contrivance, be raised or lowered and centred in the copper chamber. Deflections of the mirror from currents of air are prevented by inclosing it with a brass cover provided with a glass window. The coils are placed on each side of the copper chamber, and supported by a rod, on which they slide. By this arrangement they can be approximated until they meet and completely conceal the cylinder. By varying the position of the coils the influence of the current upon the needle can be increased or diminished. An advantage which this galvanometer possesses is the damping of the oscillation of the needle, so that it quickly comes to rest after deflection. This is accomplished by the development of induction currents in the copper cylinder, whose direction is opposite to that of the movement of the needle. The in-

strument, therefore, is aperiodic,—that is to say, that when the needle is influenced by a current it moves comparatively slowly until the maximum deflection is reached, when it comes to rest without oscillations. When the circuit is broken, the needle swings slowly back to zero, and again comes to rest without oscillations.

Inasmuch as the needle is not astatic, it is rendered so by the use of an accessory magnet,—the so-called Hauy's bar. This magnet, supported by a rod directed perpendicular to the coils, is placed in the magnetic meridian, horizontal to the needle, with its north pole pointing north. By sliding the magnet toward the needle the directive influence of the earth's magnetism is gradually diminished, and when it is reduced to a minimum the needle acquires its highest degree of instability. By means of a pulley an angular movement can be imparted to the end of the accessory magnet in the direction of the magnetic meridian, which serves to keep the needle on the zero of the scale. The deflections of the needle are observed by means of an astronomical telescope, above which is placed a scale divided into centimetres and millimetres, and distant from the galvanometer about six or eight feet. As the numbers on the scale are reversed they will be seen in the mirror in their natural position, and with the deflection of the needle the numbers will appear as if drawn across the mirror. The extent of the deflection is readily determined when the needle comes to rest.

The Capillary Electrometer.—Notwithstanding the extreme sensitiveness of the modern galvanometer, it has been found desirable, in the investigation of many physiological processes, to possess some means which would respond even more promptly to slight variations in electromotive force. This has been realized in the construction by Lippmann of the capillary electrometer. The principle of this apparatus rests upon the fact that the capillary constant or the surface-tension of mercury undergoes a change upon the passage of an electrical current, in consequence of a polarization by hydrogen taking place at its surface. If a capillary glass tube be filled with mercury and its lower end inserted into a solution of sulphuric acid, and the former connected with the positive and the latter with the negative electrode, it will be observed, upon the passage of the current, that a definite movement of the mercury takes place, in the direction of the negative electrode, in consequence of the diminution of its capillary constant or the tension of its surface in contact with the acid. As a reverse movement follows a cessation of the current, a series of oscillations will follow a rapid making and breaking of the current. If the direction of the current is reversed, the capillary constant is increased and the mercury ascends the tube toward the negative pole. From facts such as these Lippmann constructed the capillary electrometer, a convenient modification of which, devised by M. v. Frey, is shown in Fig. 5. This consists of a glass tube, *A*, forty millimetres in length, three millimetres in diameter, the lower end of which is drawn

out to a fine capillary point. The tube is filled with mercury and its capillary point immersed in a 10-per-cent. solution of sulphuric acid. The vessel containing the acid is filled to the extent of several millimetres with mercury also. The mercury in the tube is put in connection with a platinum wire (*a*), and the acid in the vessel with a second wire (*b*). When a constant current passes into the apparatus in the direction from *b* to *a* the mercury is pushed up the tube, and, upon the breaking of the current, it may or may not return to the zero-point. For the purpose of measuring in millimetres of mercury the pressure necessary to compensate this change in the capillary constant produced by the electro-motive force of polarization, the apparatus is provided with a pressure-vessel, *H*, and a manometer, *B*. This electrometer can be applied to any

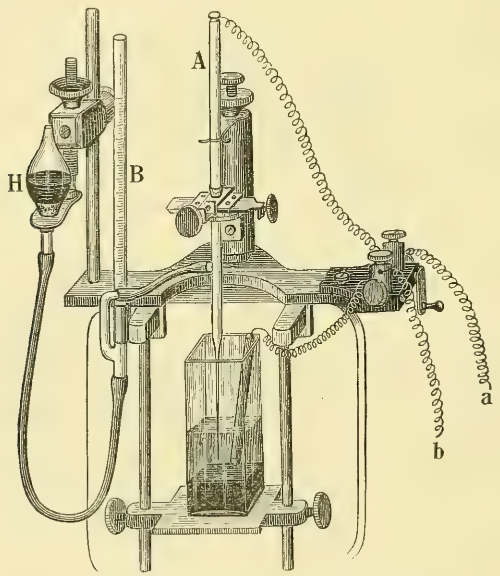

FIG. 5.—CAPILLARY ELECTROMETER.

microscope having a reversible stage. The oscillations of the mercury can then be observed with the microscope provided with an ocular micrometer. The special advantage of the electrometer is, that it will respond instantly to any variation in the electro-motive force, and indicate a difference of potential, according to Lippmann's observation, as slight as the $\frac{1}{10080}$ of a Daniell. These rapid oscillations can be recorded by photographic methods.

Electrodes.—It is essential, in the detection of weak electrical currents with highly-sensitive galvanometers, that the electrodes, which are placed in contact with the tissues, should not only be absolutely homogeneous, as the slightest difference between them will develop a current upon the closure of the circuit, but that they should also be incapable

of producing chemical changes in the tissues which would, in time, lead to a polarization of the electrodes. Should this condition be established, it would give rise to a current in an opposite direction, which would tend to weaken or neutralize the original current, whether artificial or natural. All these difficulties have been overcome by du Bois-Reymond in the construction of what he has termed non-polarizable electrodes, which are also absolutely homogeneous if correctly prepared. Du Bois-Reymond, availing himself of the discoveries of Regnauld, in 1854, that a strip of chemically-pure zinc immersed in a saturated solution of neutral sulphate of zinc, and of Matteucci, in 1856, that ordinary zinc amalgamated and immersed in the same solution, exhibited no polarization, constructed two forms of electrodes, known as diverting vessels and diverting tubes, which are of very general applicability.

The diverting vessel (Fig. 6) consists of a zinc trough insulated by a base of vulcanite, provided with a handle and a binding-screw for the attachment of wires. The inner surface of the vessel is carefully amalgamated, and the outer surface covered with a layer of black varnish. The cavity of the vessel is filled up with the deriving cushions, composed of a series of layers of Swedish filtering-paper, which are bent over the edge of the vessel. These layers are stitched together, and a clean, perpendicular edge obtained with a razor. Before using, they should be saturated with the zinc solution, and when placed in the vessel they are held in position by a strip of ebonite and a rubber band. The trough is then filled with the zinc solution. To prevent the corrosive action of the zinc solution upon the tissues to be examined, a thin clay guard is placed upon the deriving cushion. This guard consists of china-clay worked up into a soft mass with a $\frac{1}{2}$-per-cent. solution of sodium chloride. The guard not only prevents corrosion, but, from the presence of the salt, the secondary resistance which would arise between the liquid conductor and the tissues, and thus diminish the current-strength, is avoided. The diverting cylinder (Fig. 7) consists of a flattened glass tube attached to a universal joint and supported by an insulated brass stand. The lower end of the tube is closed by moistened china-clay, which can be molded into any desired shape. The interior of the tube is filled with

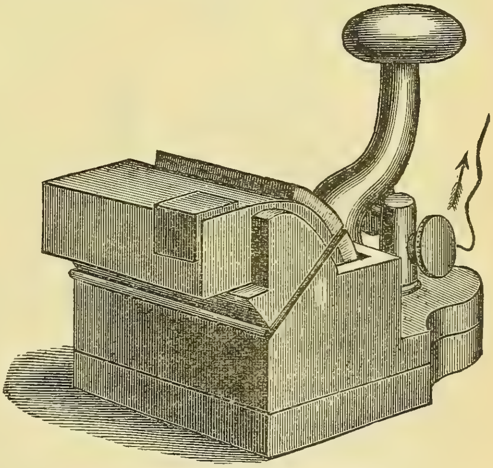

FIG. 6.—DIVERTING VESSEL.

the zinc solution, in which is immersed a slip of amalgamated zinc, the upper portion of which is lacquered. Electrodes of this form are not only serviceable for leading off currents from particular points of muscle and nerve, but are equally well adapted for purposes of electrical stimulation.

The Electrical Properties of Injured Muscles.

Individual muscle-fibres, owing to their small size, are not well adapted for experimental investigation, and present many obstacles to a study of their electro-motive properties. Research is, therefore, limited to groups of fibres as they are found in any given muscle. A complex organ, like a muscle, whose fibres are arranged in a parallel manner, furnishes results which are sufficiently accurate for the formation of definite conclusions. As the primitive bundles of fibres into which a muscle may be divided also exhibit corresponding properties, it is highly probable that individual fibres are similarly endowed, and that the electromotive properties of a muscle are the resultant of those of its component fibres.

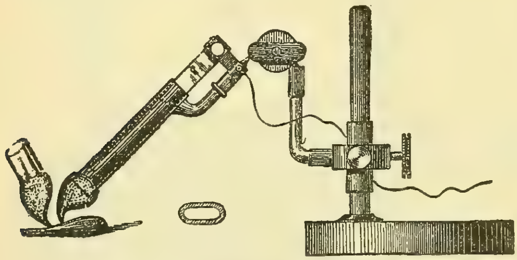

Fig. 7.—Diverting Cylinder.

The demonstration of the fundamental facts of the electrical properties of muscle is most conveniently made with single muscles, and, moreover, with those the arrangement of whose fibres is parallel, *e.g.*, the sartorius, the gracilis, or semimembranosus of the frog. Inasmuch as du Bois-Reymond discovered that the body-current is only the resultant of the currents of individual muscles, experimentation with the entire body, or even with a single limb, is wholly unnecessary.

Muscle-Prism.—If the tendinous ends of one of the above-mentioned cylindrical or oval muscles be removed by a section made at right angles to the longitudinal direction of its fibres, a muscle-prism is obtained, which presents a natural longitudinal surface and two artificial transverse surfaces. A line drawn upon the surface of such a muscle-prism, at a point lying midway between the two transverse sections, constitutes the equator. When the natural longitudinal and artificial transverse sections of a muscle-prism are brought into connection with the wires of a galvanometer whose terminals are provided with non-polarizable electrodes, an electrical current at once develops, the intensity and direction of which are indicated by the deflections of the galvanometer-needle. In all instances it is shown that the current passes from the longitudinal surface through the galvanometer to the transverse sec-

tion, and then through the muscle to the original point of departure; in other words, the former surface is electrically positive to the latter, which is electrically negative. The two points exhibiting the greatest difference of potential, and, consequently, giving rise to the most powerful current, lie in the equator and in the centre of the transverse section. Currents of gradually-diminishing intensity are obtained when the electrode placed on the longitudinal surface is removed from the equator toward either extremity. Feeble currents are developed when two points, situated at unequal distances, either on corresponding or opposite sides of the equator, are connected; in either case, the current flows from the point lying nearest the equator to the point farthest from it. Similar currents are obtained when two points on the cross-section, situated at unequal distances from the central axis, are united, in which case the direction of the current will be from the point lying nearest the periphery toward the central axis, or from the less negative to the more negative point. On the contrary, no current is generated when two points on the longitudinal surface equally distant from the equator, or two points on the transverse surface equally distant from the central axis, are united; such points are said to be iso-electrical. These conditions are shown in Fig. 8.

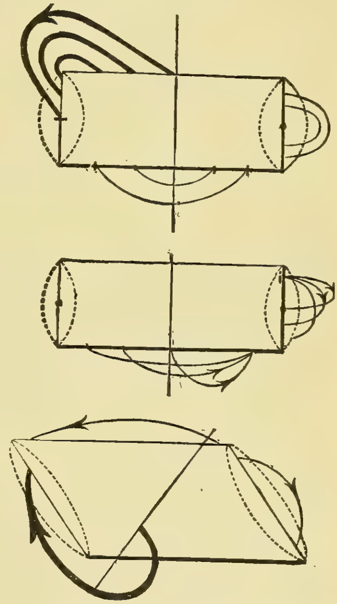

FIG. 8.—DIAGRAM TO ILLUSTRATE THE CURRENTS IN MUSCLE.

The arrow-heads indicate the direction and the thickness of the lines the strength of the currents.

From these facts it is evident that the muscle-prism may be looked upon as presenting, on its longitudinal surface, a series of tension-curves, which surround the prism in a concentric manner, and in a direction at right angles to that of its fibres. At the equator the greatest positive tension prevails, and from this point it gradually diminishes until zero is reached, at the junction of the longitudinal and transverse surfaces. In the same way the transverse section presents a series of tension-curves, all of which are negative with reference to the longitudinal surface; but, in passing from the periphery toward the centre, if the muscle be circular, the negativity gradually increases until it reaches its maximum, at the centre.

The Muscle-Rhomb.—The regularity in the position of points of unequal tension, and the simplicity of the currents when such points are connected by an arch, hold true only for regularly-constructed muscles, as represented by the muscle-prism. Deviations from this assumed normal

condition, both in the position of the points of positive and negative tensions, with reference to the longitudinal and transverse sections, and in the direction of the currents, become apparent when muscles whose fibres are irregularly arranged are subjected to galvanometric investigations. It is oftentimes very difficult to locate definitely in such muscles the positions of the points of opposite and similar potential. As an illustration of the shifting of the cardinal points, it is only necessary to examine a regular muscle-rhomb, constructed by dividing the two extremities of a regularly-constructed muscle in such a manner that the transverse sections are parallel and directed obliquely to the long axis of the fibres. In such a rhomb the fundamental law—that the longitudinal surface is everywhere positive toward the transverse surface, which is everywhere negative—holds true; but the position of the greatest positive electrical potential is no longer on the equator, but situated near the obtuse angle, from which the tension gradually declines as the acute angle is approached. The reverse of this holds true for the position of the points of greatest negative potential upon the transverse surface. Instead of being situated at the centre of the surface, it is now found near the acute angle, from which the tension declines as the obtuse angle is approached. There is, in consequence, a marked displacement in the position of the resulting currents. The equator, in such a rhomb, would be directed obliquely across the muscle, between the two obtuse angles, dividing it into two equal halves. The currents derived from obliquely-directed surfaces du Bois-Reymond has termed "inclination currents," the strength of which increases with the angle of inclination of the transverse surface. Inclination currents are observed in the gastrocnemius muscle, in which the natural transverse surface passes into the tendon in an oblique direction.

The Natural Muscle.—Electrical currents similar to those exhibited by the muscle-prism may be obtained from the natural muscle, which yet retains its tendinous or aponeurotic extremity. The natural ends of the muscular fibre inclosed by sarcolemma and tendon are spoken of as the natural transverse section. In his earlier experiments, du Bois-Reymond recognized no difference in the electrical properties of the natural and artificial cross-sections; but, subsequently, he observed that if certain precautions were taken not to injure the tendon, either chemically or physically, the negativity of the natural cross-section was inconstant. If examined immediately after removal from the body of the animal, after observing the above precautions, the electrical opposition between the longitudinal and natural cross-sections may be entirely absent, or, as is frequently the case, the latter surface may be positive in character. This is particularly true of animals which have been subjected to a temperature of 0° C. The negativity is at once developed if the tendinous expansion is chemically changed, as was the case by the saturated salt solution in the electrodes employed by du Bois-Reymond in his earlier

experiments. The layer of muscle-substance in the immediate neighborhood of the tendon which is so often neutral or even positive in its electrical relations he has termed the parelectronomic (from *para nomos*, contrary to law). All muscles possess this paralectronomic layer, and it is only necessary to remove it to make a caustic artificial cross-section, to permit the negativity of the living muscle to manifest itself.

The muscle-currents such as those above described have been shown to be present in the muscles of various representatives of mammals, birds, and reptiles, in the muscles of crustacea, and in the earthworms. The tibialis anticus, from the amputated leg of man, examined hardly a quarter of an hour after the operation, exhibited such a marked electrical difference between the longitudinal and transverse that the needle was thrown violently against the guards. (Du Bois-Reymond, "Untersuchungen über thierische Electricität," Bd. i, S. 524.) Du Bois-Reymond, to whom we are indebted for a knowledge of all the preceding facts, considers the currents to be intimately connected with the living condition of the muscle, and essential to the performance of its functions.

The Electro-motive Force of the Muscle-Current.—The muscle-current developed by connecting the longitudinal and transverse surfaces possesses an electro-motive force the amount of which can be estimated by the method of compensation devised by Poggendorff and modified by du Bois-Reymond. The idea involved in this method is to send first through the galvanometer the maximum strength of the muscle-current, and then, by means of the rheocord, to send a fractional part of the Daniell current in an opposite direction, just sufficient to neutralize the effect of the muscle-current upon the needle. When the two currents are equal and opposite in amount, the needle remains stationary at the zero-point. The fraction of the Daniell thus becomes a measure of the muscle-current, and if the rheocord wire has been previously graduated in millimetres, each of which represents a fraction of the electro-motive force of the Daniell current, it becomes a simple matter to determine the electro-motive force of the muscle in terms of the Daniell from the position of the slides on the rheocord wire. The electro-motive force of the frog-current was found by du Bois-Reymond (*Archiv für Anat. und Phys.*, 1867) to vary from 0.037 to 0.075 D.

Conditions Influencing the Development of the Muscle-Current.—As the existence of the muscle-currents is connected with those chemical changes underlying all nutritive processes, they do not disappear at once upon the death of the animal, but continue for a variable length of time, though with gradually-diminishing power. All those influences, therefore, which hasten or retard destructive chemical changes will influence the time of disappearance of the currents. Though the current diminishes in strength from the first observation, there is not infrequently observed for a short period an increase in the electro-motive force, which

has been attributed to an additional current passing from the cross-section to the longitudinal surface, developed by the contact of the fluids of the electrodes with the muscle-tissues. With the separation of the muscle from its blood-supply, it begins to experience a series of retrogressive changes which finally eventuate in rigor mortis. As this condition is approached the muscle exhibits simultaneously a diminution of its currents and a loss of its physiological properties. The dependence of the muscle-current for its existence upon the normal metabolism of the tissue is shown by the fact that, after the disappearance of the current and the beginning of rigor mortis, it will re-appear if the latter condition be removed by the introduction of a stream of fresh defibrinated blood.

Among the influences which affect in a significant manner the muscle-current must be mentioned temperature. It was originally shown by du Bois-Reymond that if a muscle be placed in distilled water at a temperature of 50° C. it contracts to a shapeless mass, loses its irritability, and becomes devoid of electrical properties. This is to be explained by the coagulation of the albuminous constituents, upon the normal composition of which the physiological and electrical properties of the muscle depend. A similar destructive influence upon the muscle-current has that degree of cold which impairs the vitality of the muscle. After thawing of the muscle no current is obtainable. Within the limits of 35° C. and 40° C., as is well known, all vital processes proceed most actively; the electro-motive force will, therefore, be increased with slight elevation, and decreased with a lowering of the temperature. According to Hermann, the variations between the above-mentioned limits will amount to as much as 22 per cent. The same observer (*Archiv für die gesammte Physiologie*, Band iv, 1871) has also shown that heating different points of the longitudinal surface renders them strongly positive toward the cooler portions, though this does not hold true for the transverse surface. Between warmer and colder portions of muscle-substance a difference of potential always exists, the condition of the parts lying between being unimportant.

The dimensions of the muscle-cylinder have also a slight influence upon the current-strength. By employing the method of compensation du Bois-Reymond has made the observation that within certain though not well-defined limits the electro-motive force increases with both the length and thickness of the muscle. By the intercalation of two corresponding pieces of muscle of unequal length in the galvanometer circuit, and by placing the electrodes in such a position that the currents conducted off pass into the galvanometer in an opposite direction, it was observed that the current from the larger muscle exerted a more powerful influence upon the needle than the current from the shorter muscle. In the same way it was shown that if two muscles the same length but of unequal thickness are opposed to each other, the thicker muscle always yields a stronger current than the thinner one.

Influence of the Contraction on the Muscle-Current.

Negative Variation.—The first accurate observations of the influence of the contraction upon the muscle-current were made by du Bois-Reymond. It was shown by this observer that as soon as the muscle enters the state of activity there is a diminution in the electro-motive force between the longitudinal and transverse surfaces, with a resulting diminution in the intensity of the muscle-current. This change in current-strength has been termed *negative variation.* In order to observe this negative variation of the muscle-current, it is only necessary to insert between the terminals of the galvanometer circuit the longitudinal and transverse surfaces of the gastrocnemius muscle. The powerful current thus obtained causes a marked deflection of the needle, which, after a few oscillations, comes to rest. If now the nerve in connection with the muscle be tetanized with the interrupted or induced current, the muscle passes into the condition of tetanus; at once the needle is observed to return toward the zero-point and remain in this neighborhood as long as the tetanic contraction continues. With the cessation of the stimulation the needle is again deflected outward by the re-establishment of the muscle-current, without, however, attaining its former position. There thus appears to be a decrease in the strength of the muscle-current during muscular contraction, the extent of which is proportional to the intensity and duration of the contraction. From the inertia of the galvanometer needle and the short duration and force of the negative variation du Bois-Reymond was unable to show this change in a single muscle pulsation. It was for this reason that tetanic stimulation was employed.

There can be no doubt that this diminution in the strength of the current is intimately connected with muscle activity, and not the result of an escape of the electrical current from the electrodes, inasmuch as the same variation follows chemical, thermal, or mechanical stimulation. Nor can it be due to any change in the position of the electrodes, for if the muscle be clamped so as to prevent displacement during the contraction the activities arising within the muscle will, nevertheless, produce a diminution of the current.

The question as to whether this negative variation during tetanus is the result of a steady, continuous decrease of the electro-motive force, or of a series of rapid and successive variations in the intensity of the muscle-current, cannot readily be shown by the galvanometer from the inertia of the needle. The physiological rheoscope, however, affords a ready means of elucidating this question. It was discovered by Matteucci that, if the nerve attached to the gastrocnemius muscle be laid upon the thigh of another animal in such a manner that the nerve forms an arch uniting negative and positive surfaces, with every contraction of the latter the gastrocnemius is thrown into pulsation. The explanation of this secondary contraction was furnished by du Bois-Reymond. The

current from the primary muscle undergoing a negativity produces a negative variation of the portion of the current which passed into the applied arch of nerve; and, as every change in the intensity of a current excites a nerve-impulse, a secondary contraction follows. Moreover, if the primary nerve be repeatedly stimulated, the thigh passes into the tetanic state, and simultaneously the neighboring muscle—the gastrocnemius—passes into the condition of secondary tetanus. As only the second muscle can be tetanized by a series of discontinuous impulses descending the nerve,—the result of rapid variations in the strength of its current,—it is evident that the primary muscle is experiencing similar variation in its electrical conditions. Confirmatory proofs of alternating variations in the strength of the muscle-current during the tetanic state are furnished by the oscillations of the mercury in the capillary electrometer and by the sonorous vibrations of the telephone when these instruments are employed instead of the physiological rheoscope.

While the above means of investigation reveal an intermittent variation in the intensity of the muscle-current, no evidence is adduced which would indicate whether it undergoes merely a partial diminution, or whether it is entirely obliterated, or whether it experiences a reversal, passing beyond the zero-point to a greater or less extent in a positive direction.

The answer to this, as well as other questions relating to the characteristics of the negative variation, was first given by J. Bernstein ("Untersuchungen über den Erregungsvorgang im Nerven und Muskelsysteme," 1871), who, by means of the differential rheotome, was enabled to study it in all its phases. The principle of this instrument consists in the rotation of a wheel at a given rate, which closes a circuit stimulating a nerve or an end of a muscle, as well as a circuit diverting the muscle-current through the galvanometer; by arranging the apparatus so that the stimulating current is closed at varying intervals before and after the diverting current, it becomes possible to determine the rate of propagation, form, extent, and time durations of this negative change. By these investigations it was shown that, after stimulation of one extremity of a muscle by an induction-shock, a definite and measurable interval of time elapses before the molecular changes thus initiated reach the electrode upon the longitudinal surface of the muscle, and which reveal themselves through the deflection of the galvanometer-needle in a direction indicating a negativity of the original muscle-current. This interval of time increases or decreases with the distance of the stimulating electrodes from diverting electrodes. Inasmuch as the time occupied by the molecular disturbance in arriving at the electrode and the length of muscle are proportional to each other, it is easy to determine the rate of propagation by dividing the latter by the former. This Bernstein calculated to be about three metres per second. It was also shown that this modification of the muscle, after its first appearance, rapidly reaches a

maximum and then more slowly declines; in other words, it propagates itself in the form of a wave. The length of time required for an entire wave to pass any given point of the muscle was estimated at 0.0033 second, from which value and from that of the rate of propagation it is easy to see that the wave-length approximates ten millimetres. With reference to the extent of negativity which the muscle-current undergoes during the contraction, Bernstein (*op. cit.*, p. 68) observed that, at the highest point of the negative wave, the muscle-current was entirely obliterated, though there was no evidence of a reversal in the opposite direction. Moreover, a further observation of interest was the apparent fact that the negative variation passes over the muscle entirely during the latent period [1] and actually precedes the movement of the contraction wave.

Burdon-Sanderson ("Proceedings of the Royal Society," May 1, 1890; *Centralblatt für Physiologie*, 1890, Band iv, S. 185), however, has brought forward incontrovertible evidence that the two processes,—the negative variation and the contraction wave,—instead of being separated in time, occur simultaneously. In these careful experiments the moment of stimulation, the electrical response as revealed by the capillary electrometer, and the change of form were recorded at the same instant by photographic methods. An analysis of the results shows that the electrical wave, instead of preceding the contraction wave, actually accompanies it. The latent period also, the time elapsing between the stimulation and the simultaneous appearance of the two processes, was shown to be very much shorter than that given by Yeo, and amounting to not more than the 0.0035 second. Sanderson concludes, from his experiments, that "all those theories, therefore, of the excitatory process in muscle which rest on the supposed fact that electrical disturbance is a concomitant of the period of latent stimulation, fall to the ground."

Electrotonus—The passage of a constant galvanic current through a limited portion of a muscle produces a change in its electrical condition to which the term electrotonus has been given. It has long been supposed that the electrotonic condition was limited to that portion of the muscle included between the two electrodes. The change of condition produced by the constant current relates to the natural muscle-current, and depends upon an inner polarization of the muscle. The constant current develops within the muscle an opposing current which may strengthen or diminish the pre-existing current according to the direction. If the constant current has the same direction as the muscle-current, the opposing current will, by adding itself to the latter, strengthen it; if,

[1] It was shown by Helmholtz (Archiv für Anat. und Phys., 1850, S. 276), in his classical researches upon the time relations of the different phases of a single muscular contraction, that a short but measurable interval of time elapsed between the application of a momentary stimulus and the beginning of the contraction, which he termed the "latent period," the duration of which he stated to be 0.01 second. Tigerstedt and Yeo have, by improved methods, reduced it to the 0.005 second.

however, the constant current is opposite in direction to the muscle-current, the opposing current will diminish the strength of the muscle-current. The electrotonic condition endures for some time, though with gradually-diminishing intensity, after the withdrawal of the constant current. Hermann (" Handbuch der Physiologie," Band ii, S. 168) states that he has been able to demonstrate the existence of the electrotonic condition also in the extra-polar region. Currents flowing in the same direction as the polarizing were obtained from the portion of the muscle in connection with the galvanometer, the strength of which increased with the latter. These currents are better developed on the side of the anode than on the side of the cathode.

Electrical Properties of Uninjured Muscle.

Currents of Rest.—The laws formulated by du Bois-Reymond as to the existence of electrical currents in uninjured as well as injured muscle, and the negative variation which they undergo during contraction, have been opposed by Professor Hermann, who, from a long series of accurate experiments, denies the existence of currents in passive and absolutely uninjured muscle, and attributes the currents which are obtained to injuries of the surface of the muscle-substance due to the methods of preparation. However carefully a muscle may be removed from the body, various points on its surface become altered chemically or physically, whereby differences of potential are established, the injured part becoming negative to the uninjured. The currents which are observed during muscular activity Hermann regards as the result of the action of electromotive forces which come into operation at the seat of excitation, and not as the result of a negative variation of pre-existent currents. To such currents the term " action currents " has been applied.

The negativity of the natural cross-section which led du Bois-Reymond to regard these currents as pre-existing in all living muscles was shown by himself to be due to the corrosive action of the salt solutions of the electrodes upon the muscle, thus causing an artificial cross-section. When this source of error was eliminated, it was noticed that the natural muscle-end exhibited electrical actions which were quite irregular in relation to the longitudinal surface, being sometimes neutral, at other times negative or even positive. This difference in the behavior of the natural and artificial cross-sections du Bois-Reymond attributed to a peculiar property of the natural end of the fibres, termed by him parelectronomia. The experiments which were subsequently made by du Bois-Reymond to obtain currents from muscles without removal of the skin were vitiated by the existence of powerful skin-currents, which were directed from without inward. These currents he was enabled to set aside, however, by destroying, at different points, the integrity of the skin by cauterization with a saturated solution of salt, after which the muscle-currents could be obtained. It was concluded, from these ex-

periments, that in animals not deprived of skin natural muscle-currents are pre-existing.

Professor Hermann did not regard this experiment as conclusive evidence for the pre-existence of the currents, and raised the objection that by the time the skin-currents were set aside by the caustic the underlying muscle-substance was also more or less injured, as, indeed, was shown to be the case when nitrate of silver was employed as the caustic agent. This he regarded as a sufficient explanation for the appearance of the current, especially as it increased in strength with the extent of cauterization. In subsequent investigations (*Archiv für die Gesammte Physiologie*, Band iii, 1870) Hermann demonstrated that, by immersing a curarized frog in a solution of corrosive sublimate for ten seconds, the skin-currents could be entirely abolished without producing any discoverable lesion of the muscular surface. After washing and drying the animal, it was only possible to obtain irregular currents of indefinite direction, and to which no physiological significance could be attached. He also succeeded in demonstrating that the gastrocnemius muscle might be so prepared by the avoidance of all pressure, change of temperature, and, above all, the contact of the irritating secretion of the skin; that it would exhibit the same want of constancy and regularity in the distribution of electrical inequalities. In fish, where from the absence of skin-glands there are no skin-currents, and where neither cauterization nor mechanical preparation is necessary, it was impossible to obtain currents from the muscles if the animal was curarized and kept at room temperatures (*Archiv für die Gesammte Physiologie*, Band iv, 1871). One of the most favorable muscles for isolation without injury is the heart, and Englemann showed, in 1874, that when examined in a state of rest no currents whatever could be detected. The same observer has also found (*Archiv für die Gesammte Physiologie*, Band xv, S. 328) that an ordinary muscle which has been divided subcutaneously, and therefore presents an artificial cross-section which is negative to the longitudinal surface, will soon again become streamless under the influence of the circulation and innervation.

From experiments such as these Hermann concludes that, in absolutely uninjured passive muscle, no current is demonstrable, and that the so-called muscle-current is intimately connected with injuries of its surface, and more especially with the artificial cross-section. All the electrical phenomena of a resting muscle depend upon the difference of potential between the living longitudinal surface and the dying transverse surface, which becomes electrically negative to the former.

Action Currents.—The currents which are obtained from a muscle during contraction Hermann regards as the result of electro-motive forces which develop during the propagation of the excitation wave, and not related in any way with a negativity of any pre-existent current. As these currents are connected entirely with the active state, he has termed

them "action currents," which, moreover, may be either phasic or tetanic as they relate to a single or a series of successive contractions. The term "phasic" is applied to the two currents which are observed when a wave of excitation passes along the muscular fibre. The first flows in the muscle, in the direction of progress of the excitation wave,—first phase; the second in the reverse direction,—second phase. These currents are due to the fact that each led-off point becomes negative with reference to the other as the excitation wave passes beneath it. The term tetanic, or decremential, is applied to the single current which is observed in a tetanized muscle, the direction of which in the muscle coincides with that of the excitation wave. In the tetanic state, in which the excitation waves follow each other in rapid succession, there should be no difference of potential, the negative tracts following each other so closely that all portions of the muscle remain in the same electrical condition. This would be the case if it were not that the wave of negativity diminishes as it travels. Hence, if any point of a tetanized muscle near the seat of excitation be compared, by means of the galvanometer, with any point situated at a greater distance from it, the former will be found negative to it. The views entertained by Hermann as to the origin and character of the action currents are based upon observations and experiments made by himself and other physiologists.

Du Bois-Reymond, in 1859, observed that when he tetanized an apparently uninjured gastrocnemius muscle, which, owing to the presence of the parelectronomic layer, exhibited no current, a descending current in the muscle always manifested itself. This descending current, or the first phase of the action current, according to Hermann, was comparable in its direction to the negative variation of the resting muscle-current. The passage of this descending current in uninjured muscle, during a single contraction, will develop a secondary contraction, and during tetanus will develop secondary tetanus; from these facts it must be inferred that to each single contraction and to the successive contractions in tetanus there corresponds a momentary descending current. This current is less marked, its development slower, and its after-effect more considerable than the negative variation of the current from an artificial cross-section.

According to the observations of du Bois-Reymond, also, when two symmetrical points on the longitudinal surface are united, no current is obtainable from the muscle, either in the resting or active condition, when stimulated through the nerve. Bernstein showed (*Monatsberichte der Berliner Acad.*, 1867, p. 444), however, when two such points are connected and the stimulation applied directly to the one end of the fibre, that with the progress of the excitation wave each led-off point became negative toward the other as the wave passed over it; in consequence, the needle indicated first a "negative," then a "positive," variation, or a diphasic action current.

The first accurate experiments undertaken with a view of analyzing the negative variation current (action current of Hermann) of an uninjured muscle during a single contraction were made by S. Mayer with Bernstein's rheotome (*Archiv für Anatomie und Physiologie*, 1868, S. 655). He employed for this purpose the gastrocnemius muscle of a non-curarized frog, connecting both tendinous ends with the galvanometer and exciting contraction by single induction shocks directed through the sciatic nerve. The excitation wave proceeded, in this instance, not from the end of the muscle-fibre, but from the end-plate of the nerve. It was observed in these experiments, from the movement of the needle, that the negative variation consists of two phases, in the first of which the lower end of the muscle becomes positive, and in the second the upper end, indicating, according to Hermann, the passage of, first, a descending, and, secondly, of an ascending action current. Holmgren, who had previously observed the same phenomena in the gastrocnemius, believed that the first phase of the negative variation took place entirely in the latent period, and the second in the stage of beginning contraction.

Hermann (*Archiv für die gesammte Physiologie*, 1877) repeated these experiments with a special apparatus,—the Fall rheotome,—by means of which the galvanometer circuit was closed by a falling body, for a brief moment, at a definite period of time after stimulation. In this way he found, contrary to former observations, that the transition of the descending into the ascending current did not coincide with the beginning of the contraction, but took place entirely in the latent period, as both phases appeared even when the rheotome was so arranged that the circuit was closed only up to the moment of contraction. Du Bois-Reymond attributed this double variation to an interference of the effects at the two ends of the muscle, for when he united the middle and tendinous end of a regularly-constructed muscle he observed only the ordinary negative variation or a single action current passing in the direction of the tendon. If both ends are led off, the currents passing in opposite directions from the point of excitation (the end-plate of the nerve), being of equal strength and requiring the same period of time for their propagation, would neutralize each other, and no deflection of the needle would result. Du Bois-Reymond supposes the negative variation here to be due to excitatory changes at the tendinous ends, which appear more suddenly and are accomplished in a shorter time at the lower end than at the upper, in consequence of which the effect from below upward has the advantage, as regards time. Hermann rejects this explanation, and asserts that when the middle and tendinous end of a regularly-constructed muscle are connected with the galvanometer and a single contraction excited through the nerve the deflections of the needle indicate a current of a diphasic character,—the first phase being atterminal, indicating a current directed toward the end of the

muscle; the second phase being abterminal, indicating a current in the reverse direction. The second phase was always found to be the weaker, and was always wanting when the end of the muscle had an artificial transverse section.

The explanation of this diphasic variation Hermann finds in the wave-like propagation of the excitation tract. As this tract appears first at the point of entrance of the nerve, and travels thence to both ends of the muscle, there must arise, as a result of the progressing negativity, first, the atterminal action current, indicating that the end of the muscle has become positive to the middle; secondly, the abterminal, indicating the reverse condition. The feebleness of the latter current, as compared with the former, arises from the decrease of the excitation wave during its propagation; and as the decrement increases with a diminution in the functional activity of the muscle, either by fatigue or gradual death, the abterminal phase gradually disappears. As the artificial cross-section cannot develop an electro-motive force, the abterminal is entirely absent.

With regard to the location of the electro-motive force giving rise to the action current, du Bois-Reymond assigns it to the parelectronomic end of the muscle. If, however, this force has its origin in the decrement, as Hermann terms it, then it ought to be distributed almost equally over the entire length of the fibre. This supposition Hermann proved true when he showed that the strength of the action current is proportional to difference in the distances of the conducting electrodes from the nervous equator, meaning by this term that cross-section of a muscle which represents the mean position of the point of entrance of the nerve.

Currents in a Living Man.—The existence of electrical currents in the uninjured muscles of a living man, though assumed by du Bois-Reymond, was rendered difficult of proof by the resistance offered by the skin, by inequalities of temperature, by glandular secretions, etc. Nevertheless, he was able to demonstrate apparently that the voluntary contraction of the muscles of an arm or leg was attended by an electrical change similar to that observed in a muscle after removal from the body, and which he regarded as a negative variation of an hypothetical resting current. The experiment made to show this was as follows: The index fingers were dipped into diverting vessels containing a salt solution, each of which was connected with the galvanometer. As the arrangement of muscles on both sides of the body is symmetrical, the currents conducted off from both fingers were equal in strength and the needle remained quite stationary. When the muscles of one arm were contracted voluntarily, a deflection of the needle took place, which indicated that the contracting arm became negative, and that a current was passing from the passive arm through the galvanometer. When the opposite arm was contracted, the deflection occurred in the reverse direction. The objections to the conclusions drawn from this experiment are numerous. Hermann denies that the current observed is the result of

changes in the muscle, but is a skin-current directed from without inward. In curarized cats it was shown that, when both feet were connected with the galvanometer, stimulation of the sciatic nerve was followed by a simultaneous secretion of perspiration and the development of a powerful current, which passed into the irritated limb. In atropinized cats, on the contrary, stimulation of the nerve was followed neither by sweating nor the development of a current, even though the muscles were contracting vigorously. From this experiment Hermann asserts that a curarized man would show the du Bois-Reymond current, even in the absence of the muscular contraction; while in an atropinized man it would be absent, in spite of the contraction.

Hermann subsequently (*Archiv für die gesammte Physiologie*, 1877, Bd. xvi) demonstrated, however, the presence of action currents during a single contraction of the muscles of the human forearm, similar to those observed by him in the uninjured muscles of the frog. The arrangement of the experiment was, briefly, as follows: The forearm was surrounded by two twine electrodes saturated with zinc solution, one being placed at the physiological middle,—the nervous equator,—the other at the wrist. Both electrodes were then connected with the galvanometer. When the brachial plexus was stimulated in the axillary space, the deflections of the galvanometer needle, when analyzed with the repeating rheotome, indicated phasic currents with each single contraction. In the first phase —atterminal—the wrist became positive, and in the second—abterminal— it became negative. The action currents which are observed in the frog's muscle were thus shown to be present in the living human muscle, with this difference, however: that the second phase,—abterminal,—instead of being weaker in man, is equally strong with the atterminal. This experiment also revealed the fact that the rapidity of propagation of the excitation wave was much greater in man, amounting to about twelve metres per second.

Theories of the Electrical Phenomena of Muscle.

The Molecular Hypothesis.—Starting from the view that the electric currents of muscles have their origin in the peculiar structure of living muscle, du Bois-Reymond assumed, in explanation of such currents, the existence in the muscle of electro-motive molecules imbedded in some indifferent medium. He supposes that the muscle consists of peripolar-electric molecules, positive at the equator and negative at either end, each of which is composed of two smaller dipolar-electric molecules with their positive ends turned toward each other. In addition to this structural arrangement, it is also assumed that every pair of dipolar molecules is inseparably united, so that injury to one is immediately followed by death of the other. It can thus be explained why every artificial surface of the muscle is negative. If the section be made between two adjacent pairs of dipolar molecules, then only negative surfaces present themselves

at the surface, and if the section be made through the positive plane of a dipolar pair, the non-injured twin molecule at once dies, thus enabling the negative surface of an adjoining molecule to present itself. To explain the parelectronomic phenomena, du Bois-Reymond assumes that at the natural end of the fibres there is a layer of bipolar "parelectronomic molecules" which do not turn the negative, but the positive, surface to the tendon.

The negative variation is explained by a decrease of electro-motive force of the molecules, or a new arrangement of them by which their electro-motive effect is weakened. The negative variation of parelectronomic muscles is explained by the hypothesis that the parelectronomic molecules, which compensate to a greater or less extent the current of the resting muscle, do not partake of the negative variation to the same degree as the normal molecules, and, in consequence, their own variation is unable to compensate that of the remaining normal part of the muscle. It is for this reason that a streamless parelectronomic muscle shows the same variation as if it had an artificial cross-section. The negativity of the excitation wave is explained by the further assumption that the portion of the muscle being stimulated represents a relatively indifferent conductor, because its former positivity is now momentarily abolished from the negative variation of its molecular forces. The negative electricity, therefore, which is always present at the negative cross-sections of the resting part, is simply conducted to the stimulated part, which becomes momentarily negative.

The Alteration Hypothesis.—In 1867, Professor Hermann proposed a new theory as to the origin of the electro-motive forces which, so far, has apparently explained all the phenomena. He terms this the alteration theory, because it reduces all electro-motive phenomena of muscle to a two-fold alteration of its substance. In the first place, he starts from the fact that a section of a muscle is followed, in a short time, by death of the contents of its fibre. Assuming that the dying substance reacts negatively toward the living, he is enabled to explain readily and satisfactorily all the phenomena of the resting muscle. As the electro-motive force, according to this view, has its seat at the surface of separation between the dying and living substance, he terms the current the demarkation current. The phenomena observed during activity are further explained by the simple and plausible assumption that not only beginning death, but even stimulation, makes the affected substance negative to the remainder of the muscle. All the forms of action currents can thus be explained without any further auxiliary hypothesis.

Hermann regards the following four propositions sufficient to explain the origin of all the galvanic phenomena of living tissues: 1. Localized death in continuity of protoplasm, whether caused by injury or by metamorphosis (mucous, horny), renders the dead part negatively electrical to the unaltered part. 2. Localized excitation in continuity

of protoplasm renders the excited part negatively electrical to the unaltered part. 3. Localized warming in continuity of protoplasm renders the warm part positive; localized cooling, the cold part negative to the unaltered part. 4. Protoplasm is strongly polarizable on its limiting surfaces (first shown as regards the protoplasm inclosed in tubes of muscles and nerves); the polarization constant decreases on excitation and on dying. ("Translations of Foreign Biological Memoirs," 1887, p. 328, edited by Burdon-Sanderson.)

Electrical Properties of Injured Nerves.

After the discovery of the existence of electrical currents in muscles, numerous attempts were made to determine the existence of similar currents in nerves and to identify, if possible, the nerve-principle with electricity. It was reserved for du Bois-Reymond, however, to first definitely detect the presence of electrical currents in nerves, which he was enabled to do by means of the improved methods of investigation alluded to in the previous section. This observer discovered that the electrical properties of nerves have a striking similarity to those of muscles, and that the laws governing the latter are equally applicable to the former.

Nerve-Cylinder.—The nerve-cylinder, obtained by making two transverse sections of any given nerve at right angles to its long axis, is best adapted for the application of the nerve-current. Such a cylinder presents, as in the case of the muscle, a natural longitudinal surface and two artificial transverse surfaces; a line drawn around the nerve-cylinder, at a point lying midway between the two end-surfaces, constitutes the equator. An artificial longitudinal surface is difficult to obtain, from the small size of the nerve-bundles. The electrical phenomena of the nerve-cylinder, when examined with the galvanometer, are found to obey the same laws as those governing the muscle. Strong currents are obtained when the natural longitudinal and the transverse surfaces are placed in contact with the diverting cushions of the electrodes. The direction of the current, of which the deflection of the needle is an indication, is constantly from the longitudinal surface through the galvanometer to the transverse surface. The strength of the current obtained by uniting these two surfaces will diminish or increase, according as the electrode on the longitudinal surface is removed or brought near to the equator. Weaker currents are obtained when two asymmetrical points on the longitudinal surface are connected, in which case the point lying nearer the equator becomes positive, to that more distant, which is negative. When two symmetrical points on the longitudinal surface, equidistant from the equator, are united, no current is obtainable. From these facts it is evident that all points on the longitudinal surface of the nerve-cylinder are electrically positive to the transverse surface, and that the point of greatest positive tension is situated at the equator, from which it grad-

ually decreases toward the transverse section. As to whether this latter surface exhibits differences of potential between its centre and circumference it is difficult to determine, as the small area of the surface excludes it from accurate investigation, though it is quite probable, from the analogous electro-motive properties of muscle, that similar differences of potential are present. Mendelssohn (*Archiv für Anat. und Physiologie*, 1885) has recently shown that when the two transverse sections of a nerve-cylinder are united, a current—the axial current—is obtained which flows in the nerve in a direction opposite to that of the direction of the nerve-impulse. In motor or efferent nerves it flows from the periphery toward the centre, and in sensory or afferent nerves in the contrary direction. The small size of the nerve-trunks renders an investigation of oblique surfaces for evidences of inclination currents impossible.

The Electro-motive Force.—The electro-motive force of the nerve-current, obtained by uniting the longitudinal and transverse surfaces, varies in strength with the length and thickness of the nerve, a long section of a nerve showing, under similar conditions, a more powerful current than a short section, while a nerve with a large transverse section will exhibit a stronger current than a nerve with a small transverse section. From the experiments of du Bois-Reymond, the electro-motive force of the strongest nerve-current in the frog is equal to the 0.002 of a Daniell, and in the rabbit to 0.026 D.

Conditions Influencing the Development and Duration of the Nerve-Current.—The current present in any given nerve-fibre does not disappear at once upon the death of the body, but disappears gradually until, sooner or later, it entirely ceases to manifest itself. After the transverse section of a nerve-cylinder has ceased to exhibit negativity in relation to the longitudinal surface, independent of either mechanical or chemical injuries, the production of a new section will be followed by a return of the current in its original intensity. Inasmuch as the development of the current is intimately related to the living condition of the nerve, all those influences which hasten the molecular disintegration will cause a disappearance of the current. Excessive heat or cold, mechanical injuries, acids, alkalies, repeated induction shocks, all tend, through the production of changes in the contents of the nerve-fibre, to diminish the current. The duration of the current varies considerably in different parts of the nervous system and in different classes of animals, there being no physiological change comparable to that producing rigor mortis in muscles, which determines definitely the cessation of the current. Indeed, there does not appear to be any absolute connection between the existence of excitability and the development of the current, as the observations of Schiff ("Lehrbuch der Muskel und Nervenphysiologie," 1858, S. 69) have shown that after separation from the central nervous system the nerves will exhibit a current for from eight to fourteen days

after they have lost their excitability through degenerative changes. The electro-motive forces disappear first in the nerve-fibres of the brain, then of the spinal cord, and lastly in the nerves themselves, and in a direction from their origin toward their termination. In warm-blooded animals, both mammals and birds, the electro-motive properties disappear more rapidly than in cold-blooded animals, most probably in consequence of the more rapid decline of all those chemical changes underlying the general nutritive process. Not unfrequently in warm-blooded animals, less frequently in frogs, a reversal of the current is observed, more especially if the nerve be rapidly dried or subjected to heat, although the same phenomenon is observed under normal conditions. In the latter case, it has been attributed to an accumulation of electrolytic products at the limiting surface, which have given origin to a polarization current flowing in a direction opposite to that of the natural current.

The Influence of Stimulation upon the Nerve-Current.

Negative Variation.—It was shown by du Bois-Reymond, shortly after the discovery of the nerve-current, that the activity of the nerve, as well as the activity of the muscle, is accompanied by a change in its electro-motive condition or a diminution of potential between the longitudinal and transverse surfaces, and in consequence a negative variation of the natural pre-existing current. This change in the electro-motive forces can be readily demonstrated by means of the galvanometer during tetanic stimulation, or by the capillary electrometer during a momentary stimulation by a single induction shock. When the transverse and longitudinal surfaces are connected with the terminals of the galvanometer wires, and the current permitted to deflect the needle, stimulation of the nerve is at once followed by a return of the needle toward the zero-point, indicating a diminution in the strength of the natural current; with the cessation of the stimulation, the needle is again deflected outward to its previous position, indicating a re-establishment of the electro-motive forces. This negative variation of the current is observed equally well whether the current is conducted from the central end and the periphery stimulated, or whether the current is conducted from the peripheral end and the central stimulated. Indeed, if both ends are connected with galvanometers and the nerve stimulated in the middle, the negative variation is observed simultaneously at both ends. The excitation propagates itself, therefore, equally well in both directions.

Du Bois-Reymond, in his investigations, found that the negative variation was intimately connected with changes in the molecular condition of the nerve, and not to an escape of the current into the galvanometer circuit, nor to the establishment of an electrotonic condition, nor to an increase in the resistance of the nerve. In these respects the phenomenon is comparable to that observed in the muscle. As a further proof that the negative variation is not the result of any extraneous

electrical influence, it is only necessary to employ chemical, mechanical, or thermal agents for purposes of stimulation. Whatever the character of the exciting agent may be, provided it is sufficiently powerful, a negativity of the current is always observed. Du Bois-Reymond was also enabled to obtain a negative variation of the current in the nerves of a living frog which were yet in connection with the spinal cord. In this experiment the sciatic nerve was divided at the knee and freed from its connections up to the spinal column; the transverse and longitudinal surfaces were then placed in connection with the electrodes of the galvanometer wires and the current permitted to influence the needle. The animal was then poisoned with strychnine. Upon the appearance of the muscular spasms the needle was observed to swing backward toward the zero-point to the extent of from 1 to 4 degrees, and, upon the cessation of the spasms, to return to its previous position. In an experiment of this nature it is obvious that the negative variation was the result of a physiological stimulation of the nerve arising within the spinal cord.

The question also here arises as to whether the negative variation is due to a steady, continuous decrease of the natural current, or whether it is due to successive and rapidly-following variations in its intensity, similar to that observed in muscles. Though this cannot be demonstrated with the physiological rheoscope, as was the case with the muscle, there can be no doubt, both from experimentation and analogy, that the latter supposition is the correct one. Wedenskii (*Centralblatt für die Med. Wissenschaft*, 1883–1884) has shown that when non-polarizable electrodes connected with Siemen's telephone are placed in connection with the longitudinal and transverse sections of a nerve, low, sonorous vibrations are perceived during tetanic stimulation,—a proof that the active state of the nerve is connected with the production of discontinuous electrical currents. The oscillations of the mercurial column of the capillary electrometer also reveal similar electrical changes.

It was also shown by Bernstein ("Untersuchungen u. d. Erregungsvorgang im Nerven- und Muskelsysteme," 1871), with the repeating rheotome, that the negative variation is composed of a large number of single variations, which succeed each other in rapid succession, and summarize themselves in their effect upon the needle; that the change in the nerve which follows the stimulation propagates itself in the form of a wave, whose length has been estimated at eighteen millimetres, and whose time duration is about 0.0007 of a second. The rapidity with which the negative variation travels through the nerve of a frog is about twenty-eight metres per second.

Electrical Properties of the Uninjured Nerve.

Currents of the Resting Nerve.—The pre-existence of electrical currents in living and wholly-uninjured nerves has also been denied by Professor Hermann, who regards all portions of the nerve as iso-electrical,

any difference of potential being the result of some mechanical or chemical injury to its surface. As to whether the natural transverse section would exhibit a negativity with reference to the longitudinal surface, it is almost impossible to determine by direct experimentation, as the terminations of the nerves, both central and peripheral, are deeply imbedded in tissues, which themselves are the seat of electro-motive forces, and which cannot be distinguished, by present means of investigation, from those of the nerves. The existence of a parelectronomic layer at the periphery of the nerve which would, under certain circumstances, exhibit a positive electrical tension is, for this reason, impossible to state. The only currents thus far observed are those obtained by uniting the longitudinal and artificial transverse sections.

Action Currents.—For reasons to be stated below, it is very difficult to determine the presence of diphasic action currents during the passage of an excitatory impulse through the nerve-fibre. The so-called negative variation of the resting-nerve current,—the demarkation current,—which passes from the transverse to the longitudinal surface, and which is occasioned by tetanic stimulation, Hermann regards as the expression of an action current which flows in the nerve in an opposite direction to the natural current. The origin of this action current is to be sought for in the continuous negativity of that portion of the longitudinal surface of the nerve in contact with the diverting electrode, while the dying substance of the transverse surface takes no part in the excitation. This tetanic action current, or negative variation, was discovered by du Bois-Reymond. Bernstein also succeeded in obtaining this action current with the differential rheotome during the passage of a single excitation wave. When any two points in the longitudinal surface which exhibit no current are connected with the galvanometer and a single wave of excitation passes beneath the electrodes, it might be expected that, as in the case of the muscle, a diphasic action current would be observed, from the fact that the portions of the nerve beneath the electrodes became alternately negative with reference to all the rest of the nerve. This, however, is not the case, the absence of the two opposing phases of the action current being explained on the supposition that the negativity of the two led-off points is of equal amount, and that, owing to the great rapidity with which the excitation wave travels, the two phases fall together too closely in time to alternately influence the galvanometer needle. During stimulation of the nerve, when two currentless points are connected, there is also an absence of the action current, as was observed first by du Bois-Reymond, and which is to be explained on similar grounds. It is true that an apparent action current is sometimes seen when the stimulating current is very powerful or the seat of stimulation too near the diverting electrodes. This, however, must be attributed to an electrotonic state of the nerve.

INFLUENCE OF A CONSTANT GALVANIC CURRENT ON NERVES.

In investigating the electric phenomena of nerves, du Bois-Reymond ("Untersuchungen über thierische Electricität," Bd. ii, S. 289) discovered, in 1843, that the passage of a constant galvanic current through a portion of a nerve produced a change in the electro-motive forces existing between the longitudinal and transverse surfaces, whereby the resulting nerve-current was either increased or diminished, according to the direction of the constant current. To this condition du Bois-Reymond applied the term electrotonus. It was subsequently shown by Pflüger (" Untersuchungen über die Physiologie des Electrotonus," 1859) that a definite change in the irritability of the nerve is also caused by the passage of the galvanic current, and, as it is intimately related to the change in the electro-motive forces, he applied to this alteration of excitability also the term electrotonus. This word has thus been employed to express two distinct series of effects exhibited by a nerve through a portion of which a constant galvanic current is passing. It appears desirable, for the sake of clearness, to limit the term electrotonus to the electrical or electrotonic currents which can be led off from either extremity of the nerve, and to apply to the modifications of irritability which accompany electrotonus the expression electrotonic alteration of excitability. The electrotonic currents and the associated changes in the nerve-excitability, while intimately related to each other, are, nevertheless, two distinct effects of the constant current, and can be studied independently of each other.

Electrotonus.—If a nerve be so arranged that its longitudinal and artificial transverse surfaces are connected with the terminals of the galvanometer, the deflections of the needle will indicate the usual nerve-current. The passage of the constant current through the portion of the nerve beyond the diverting electrodes will then produce a change in the strength of the nerve-current which will vary according to the direction of the experimental or " polarizing " current. If this current be transmitted through the nerve in a direction corresponding to the nerve-current, the latter will be strengthened or increased, thus constituting the positive phase of electrotonus. If the polarizing current be transmitted in the reverse direction, the natural nerve-current is weakened or decreased, thus constituting the negative phase of electrotonus. The same positive and negative phases, however, are observed when any two points on the longitudinal surface are connected with the galvanometer and the polarizing current applied to the projecting end of the nerve; the deflections of the needle indicate the existence of electrotonic currents having the same direction as the polarizing current. The natural nerve-currents have, therefore, no connection with the electrotonic currents, except in a purely accidental way, as the latter are present even when the former are entirely absent. These fundamental experiments indicate that when a constant galvanic current is flowing

through a limited portion of a nerve, all other portions exhibit the presence of electrical or electrotonic currents, which are in some way dependent upon or related to the galvanic current. The electrotonic current in the neighborhood of the positive pole, or anode, is called the anelectrotonic current, and has, in the nerve, a direction toward the polarized region. The current in the neighborhood of the negative pole, or cathode, is called the catelectrotonic current, and has, in the nerve, a direction away from the polarized region.

The electrotonic currents vary considerably in strength and extent, according to the intensity of the polarizing current, increasing steadily with the intensity of the latter without attaining a maximum so long as it is not destructive in its action upon the integrity of the nerve. The electro-motive force of these currents surpasses that of the natural currents, as shown by the method of compensation, and may amount to 0.5 Daniell. The electrotonic current is strongest in the immediate neighborhood of the electrodes, but gradually diminishes in strength as the distance between the polarized and led-off portions is increased. The distance to which the electrotonic currents extend along the nerve will depend very largely upon the strength of the polarizing current, though it is conditioned by the physical state of the nerve; for if it be ligated or injured beyond the polarized portion the current is abolished.

Other conditions being equal, the strength of the anelectrotonic current is greater than the catelectrotonic. When means are taken to increase the electro-motive force of the polarizing current, *pari passu* with the increasing resistance of the nerve both currents are increased in intensity in proportion as the polarized region is increased in extent. The electrotonic condition is established at the instant the polarizing current is closed, and disappears rapidly after it is opened, even when it is of short duration. Momentary currents, such as single induction shocks, are sufficient to develop electrotonus. The anelectrotonic current, after its origination, increases slowly, attains its maximum, and then gradually declines; the catelectrotonic current, on the contrary, attains its maximum much more quickly, and declines also more rapidly.

From the preceding statements, it is evident that the electrotonic current differs in many respects from the resting-nerve current, as well as from the action current, and is not the outcome of an excitatory state of the nerve, but that it is rather of artificial origin, connected in some way with the polarizing current. That it is not merely due, however, to an escape of the latter into the galvanometer circuit is evident from the fact that other structures, such as dead or degenerated nerves, wet threads, etc., which offer favorable conditions for the current escape, do not exhibit electrotonic currents. These facts would indicate that the phenomena of electrotonus are dependent upon the living condition of the nerve, or at least upon its anatomical integrity.

Polarizing After-Currents.—The passage of a constant galvanic current through a nerve produces an internal polarization which gives rise, upon its withdrawal, to after-currents, whose extent and direction can be determined by galvanometric observations. If the intra-polar region be connected with the galvanometer, the deflection of the needle will indicate immediately, upon the opening of the galvanic current, an after- or internal polarization current, the direction of which will depend upon the strength and time of closure of the former. When the galvanic current is strong and of short duration, the after-current is always *positive*,—that is, has the same direction as the polarizing current itself; on the contrary, the after-current is always *negative*,—that is, has a direction the reverse of the polarizing when the latter is feeble and long-continued in its action. The positive after-current is especially well developed when the direction of the galvanic current is the same as that of the propagation of the normal nerve-impulses. The presence of after-currents can also be shown in the extra-polar regions. Immediately upon the opening of the galvanic current, the deflection of the galvanometer needle indicates that the after-current in the anodic region is at first in the same but subsequently in the opposite direction to that of the anelectrotonic current, while the current in the cathodic area is always in the direction of the catelectrotonic current.

Secondary Contraction from a Nerve.—It was shown by du Bois-Reymond that when an excised nerve was laid on the sciatic nerve of a nerve-muscle preparation, stimulation of the former was always followed by contraction or even tetanus of the muscle, according as the stimulation was momentary or continuous. At first glance it might be supposed, from the analogy of secondary contraction from a muscle, that in this instance also the contraction might be due to a variation of the natural nerve-current or to an active current which would excite an impulse in the second nerve. That this is not the explanation of the contraction, however, is evident from the fact that stimulation of the nerve by any other than electrical means fails to excite a contraction. It was for this reason that du Bois-Reymond attributed the generation of the nerve-impulse in the second nerve to the development of the electrotonic condition. When the primary nerve is traversed by the electrical current, whether induced or galvanic, and passes into the electrotonic state, the secondary nerve also develops a secondary electrotonus, which persists as long as the nerve is traversed by the current. Upon the opening of the latter the secondary electrotonus also at once disappears. It is this alternate appearance and disappearance of the secondary electrotonic condition to which the excitement of the nerve giving rise to the contraction must be attributed.

A striking illustration of the production and stimulating effects of secondary electrotonus is offered by the so-called "paradoxical contraction," first observed by du Bois-Reymond ("Untersuchungen über thier-

ische Electricität," Bd. ii, S. 545). The sciatic nerve of the frog divides at the lower third of the thigh into two branches,—the tibial and the peroneal,—the former of which supplies principally the gastrocnemius and the tibialis posticus muscles. If the sciatic nerve be divided above and the peroneal nerve below the point of separation, and the latter stimulated by alternately opening and closing the constant current, the gastrocnemius at once contracts and, if the stimulation be sufficiently rapid, passes into the tetanic condition. The explanation of this contraction rests, as above mentioned, in the establishment of a secondary electrotonus.

Electrotonic Alterations of Nerve Excitability.—In addition to the electrotonic state into which the nerve passes upon the passage of a constant galvanic current through a portion of its extent, there is also produced a marked alteration in both its excitability and conductivity, whereby the results of nerve stimulation, muscular contraction, and sensation are increased or decreased, according to the strength and direction of the current.

The first accurate observations upon the alterations of the excitability were made by Valentine (" Lehrbuch der Physiologie des Menschen," 2 Auflage ii, S. 655), who discovered that the excitement aroused in a nerve experienced great difficulty in passing through the portion of the nerve traversed by the constant current, and that, if the latter were ascending, an irritant applied between it and the muscle was much less efficient in exciting muscular contractions. Eckhard (*Zeitschrift für rationale Medizin*, 2, iii, S. 198) continued and extended these observations with improved methods of research, and discovered the fact that the excitability of the nerve was always increased below the portion through which a descending current was passing He also surmised that the excitability above this portion was decreased, and, in consequence, formulated the law that the excitability is increased on the side of the cathode and decreased on the side of the anode. Pflüger finally (" Untersuchungen über die Physiologie des Electrotonus," 1859), with the aid of improved and accurate methods of investigation, enlarged our knowledge of the changes in excitability caused by the action of the galvanic current, and arranged and co-ordinated them under one general law, as follows: If any portion of a nerve be traversed by a descending or an ascending constant current, the excitability of the intra-polar as well as the extra-polar regions undergoes a change which, upon investigation, is found to be decreased in the neighborhood of the anode, or positive pole, and increased in the neighborhood of the cathode, or negative pole. The zone of diminished excitability, and to which Pflüger gave the name of anelectrotonus, extends for some distance on both sides of the anode; the zone of increased excitability, or catelectrotonus, extends in a similar manner on both sides of the cathode. These alterations of the normal excitability are most marked in the

immediate vicinity of the electrodes, but extend for some distance into both the intra- and extra- polar regions, though with gradually-diminishing intensity, until they finally disappear. Between the electrodes there is a point where the anelectrotonic and catelectrotonic states merge into each other, and at which the normal excitability of the nerve is preserved. This is known as the neutral or indifferent point. The degree to which the excitability is increased at the negative and decreased at the positive pole, and the extent to which these alterations spread themselves into both the intra- and extra- polar regions, will depend largely upon the strength of the constant current and the normal excitability of the nerve. If, while the nerve is traversed by currents of varying degrees of intensity, it be tested at all points with reference to the change in its excitability, a series of results will be obtained which can be represented graphically somewhat according to the accompanying illustration. Let the abscissa line *N N* represent the nerve, the decrease in the excitability of which is indicated by an ordinate directed downward, and the increase in excitability by an ordinate directed upward. The electrodes

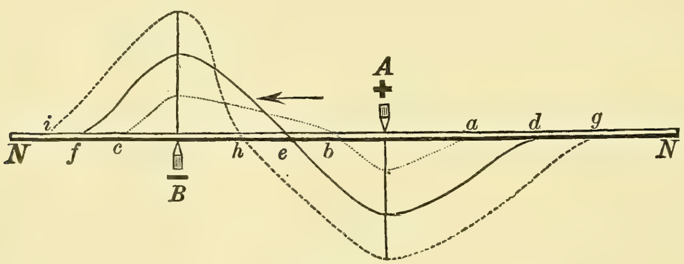

FIG. 9.

conveying the current to the nerve are represented by *A*, the positive, and *B*, the negative pole. The relative extent of the alterations of the excitability, as revealed by the energy of the muscular contraction following the application of a uniform stimulus, is shown by the three curves, the size and extent of which represent the changes produced by a weak, medium, and strong current. The curve also shows that with a weak current (*a*, *b*, *c*) the excitability in the anodal zone is decreased and in the cathodal zone increased, and that the neutral point, *b*, lies close to the side of the positive pole.

From this point the changes in the excitability gradually increase, and reach their maximum in the neighborhood of the electrodes, from which both phases gradually decline. The position of the neutral point also indicates that by far the larger portion of the intra-polar region is in the condition of increased excitability, or catelectrotonus. The curve *d*, *e*, *f*, similar in its general form to the preceding, represents the alterations in the excitability produced by a current of medium strength; *pari passu* with the increase in current-strength, there is an increase in

the amount of both anelectrotonus and catelectrotonus and the distance to which they spread themselves into the extra-polar regions. The indifferent point has advanced toward the centre of the intra-polar region, indicating that this portion of the nerve is almost equally occupied with the opposed states of excitability. The curve g, h, i represents still further the same changes following the employment of a strong current. The neutral point has now been shifted toward the cathode, and the intra-polar portion is in the condition of anelectrotonus.

The demonstration of corresponding changes in the excitability of the nerve in the intra-polar region presents many difficulties, owing to the close proximity of the electrodes conveying the polarizing and the stimulating currents and their consequent interference with each other. Pflüger overcame this difficulty by employing as the testing agent a concentrated solution of salt, and succeeded in demonstrating the above-mentioned intra-polar changes. From this fact it is clear that the changes in the excitability are not dependent upon or related to the special nature of the electrical stimulus, as they exhibit themselves upon the application of all forms of stimuli, whether chemical, mechanical, or thermal.

In order that the opposed electrotonic conditions of the nerve may correspond with the direction of the electrotonic currents, the region $A\ g$ (Fig. 9) is designated as that of extra-polar descending anelectrotonus, and the region $B\ i$ as that of extra-polar ascending catelectrotonus, when g represents the central and i the peripheral end of a motor nerve. When the conditions are reversed, however,—that is, when i is the central and g the peripheral end,—then the region $A\ g$ is termed that of the extra-polar ascending anelectrotonus, and the region $B\ i$ as that of descending catelectrotonus. The conditions of ascending catelectrotonus and anelectrotonus cannot, without much difficulty, be directly proved, owing to the fact that the excitement following an irritation applied to the ascending regions must traverse the portion of the nerve through which the constant current is passing, as well as through the portion which is already in the opposite electrical condition. The conductivity of the nerve appears to be impaired in the neighborhood of the anode,—a condition which increases with the decrease in the normal excitability. On the contrary, the excitation originating in the descending catelectrotonic and anelectrotonic regions passes directly, without interference, into the muscle. Hence it is that only in these regions can the law of the electrotonic changes in the excitability be successfully demonstrated.

The excitability of the nerve which has been altered in the manner related above, during the passage of the constant current, undergoes yet further modifications immediately upon the opening of the current. The normal condition is not at once re-established, this being regained only after the lapse of some minutes, especially if the current has been strong and of long duration. These after-results of the action of the

constant current have been carefully investigated by Pflüger, who has termed the increase of excitability the positive modification, the decrease of excitability the negative modification. If, for example, the nerve be examined with reference to these changes, it will be found that the excitability in the region of the anode will undergo a positive modification which lasts for a few seconds only, after which it returns to the normal condition. In the region of the cathode the excitability passes in a similar manner for a few seconds into a negative phase, after which it again undergoes a continuous positive modification which may last for a variable length of time. Its duration appears to be a function of the current-strength, for, with feeble currents, it lasts from one to two minutes, with strong currents from ten to fifteen minutes. The opening of the constant current very frequently produces in the nerve such a change in its excitability that a series of pulsations or an apparent tetanus follows, which has long been spoken of as the opening tetanus of Ritter.

The Law of Contraction.—The general law of electrical stimulation was first accurately formulated by du Bois-Reymond in 1845, in the following words: "It is not the absolute value of the current density at any moment to which the motor nerve reacts, as shown by the contraction of its related muscle, but the change of this value from one moment to another; the stimulus to the contraction which follows these changes is the more considerable the more rapidly they follow each other, or the greater they are in any unit of time." From this law it follows that the mere passage of a constant current through a nerve does not, in general, excite it to activity, this being accomplished only by a change in the current-strength. These variations, however, must occur with a certain rapidity, otherwise even the strongest currents have no appreciable effect when they are very gradually increased or diminished. The sudden variation of a weak current is often very effective in the stimulation of a nerve. The exact law, however, of the dependence of stimulation upon variations in current-strength has not yet been definitely stated, but it is probable that within certain limits the sought-for function consists in a simple proportionality.

There are certain facts which appear, however, to contradict the general law just mentioned. With regard to the centripetal nerves, it is well known that, independent of the sensations which occur upon the opening and closing of the circuit, the constant flow of the current also gives rise to persistent sensations, which may become unbearable. But, as Professor Hermann remarks, an exact analysis of these phenomena shows that the sensory end organs, as well as the sensory central organs, are not sufficiently excluded to justify a change in the general law, as the end organs are so constituted that they are stimulated not only by variations, but also by constant conditions. With regard to centrifugal nerves, it was observed by du Bois-Reymond that tetanizing effects occa-

sionally follow the passage of very strong currents; and, as they continue after the cessation of the current, he attributed them to an electrolytic change in the nerve. It was subsequently shown by Pflüger, however, that weak constant currents also had a tetanizing effect, even when all polarization of the electrodes was carefully excluded. He assumes, therefore, that the nerve is stimulated by the steady flow of the current, as well as by variations in its strength, and that probably the stimuli proceed from the cathode. If the constant current is capable of developing stimuli, it must be assumed either that they are very weak, as compared with those produced by a sudden variation in the strength, or that their character is such that not every organ is capable of responding to them.

The law of contraction, which expresses the effects in a motor nerve which follow the closure and opening of the constant current, has been established by the observations of many physiologists. Pfaff made the discovery, in 1793, that for the occurrence of a closing or an opening contraction it was not a matter of indifference whether the current in the nerve was ascending or descending in its direction. Ritter, in 1798–1805, made an elaborate series of experiments, the chief merit of which was the discovery of the influence which the excitability of the never has upon the law of contraction. In 1829 Nobili stated clearly, for the first time, the law of contraction free from Ritter's theory of a contrast between flexors and extensors. This was confirmed by du Bois-Reymond in his classic investigations, and later by Heidenhain, who, in addition, first determined the influence of the intensity of the current upon the results obtained. Corresponding, in many respects, to the law of contraction as stated by previous observers, is that of Pflüger's, as follows :—

CURRENT INTENSITY.	ASCENDING CURRENT.		DESCENDING CURRENT.	
	Closing.	Opening.	Closing.	Opening.
Weak	Contraction.	Rest.	Contraction.	Rest.
Medium	Contraction.	Contraction.	Contraction.	Contraction.
Strong	Rest.	Contraction.	Contraction.	Rest or weak contraction.

Pflüger attempted to explain all the phenomena of the above law of contraction on the assumption that the current stimulates the nerve only at the one electrode, at the cathode in closing, and at the anode in opening, or, in other words, by the appearance of catelectrotonus or by the disappearance of anelectrotonus,—not, however, by the opposite changes. He further assumes that the appearance of catelectrotonus is more effective in exciting the nerve than the disappearance of anelectrotonus. The law

of contraction can, then, be explained as follows: Very feeble currents, either ascending or descending, produce contraction only upon the closure of the circuit, the sudden increase of the excitability in the catelectrotonic area being alone sufficient to generate an impulse. The contraction which follows the closing of the ascending current depends upon the fact that the decrease of excitability at the anode is insufficient to interefere with the conduction of the cathodal stimulus. Medium currents, either ascending or descending, produce contraction both in closing and opening the circuit. The appearance of catelectrotonus and the disappearance of anelectrotonus are both sufficiently powerful to generate an impulse without, however, impairing the conductivity of the nerve.

Very strong currents produce contraction only upon the opening of the ascending and closure of the descending currents, or upon the passage of the excitability in the former from the marked anelectrotonic decrease to the normal condition, and in the latter from the normal to that of catelectrotonic increase, the absence of contraction upon the closure of the ascending current being dependent upon the blocking of the cathodal stimulus by the decrease of the excitability at the anode. With the opening of the descending current the disappearance of anelectrotonus should also be followed by contraction, which would indeed be the case if the stimulus so generated was not blocked by the sudden decrease of the conductivity at the cathode.

Nothing analogous to the law of contraction has as yet been observed in secretory nerves, but Donders confirmed it in his experiments upon the inhibitory fibres of the vagus.

Experiments on Man.—The preceding statements as to changes in the excitability produced by a constant current, as well as to the law of contraction, are based entirely upon experiments made on the isolated nerve of the frog, and under what may be regarded as abnormal conditions. It is not to be expected, therefore, that the results which have been obtained by the application in the same manner of a constant current over the course of a human nerve, surrounded by tissues possessed of different degrees of resistance, would strictly correspond to those obtained by purely physiological methods. Nevertheless, when rightly applied, the physiological effects of the constant current on the normal human nerves, though differing somewhat in detail, are the same in principle, and confirm Pflüger's laws.

Eulenburg (*Deutsches Archiv für klinische Medicin*, Bd. iii, S. 117, 1867), in his investigations of the electrotonic effects of the constant current applied percutaneously in man, found Pflüger's law confirmed, and stated his results in the following words: "There can be no doubt that, by the percutaneous application of stable galvanic currents of moderate intensity, we can succeed in producing phenomena in superficially-lying motor nerves which agree very well with those of the descending extra-polar anelectrotonus and descending extra-polar catelec-

trotonus,—*i.e.*, in producing in the first case a negative and in the second a positive increment of the excitability of that part of the nerve lying behind the current. He admitted, however, that differences sometimes occurred, and attributed them to the influence of the undisturbed nutrition of the nerve, and to central innervation modifying the electrotonic excitability. Erb (*Deutsches Archiv für klin. Med.*, Band iii, S. 238, 513, 1867), however, found, as a constant result of many experiments, performed according to the usual physiological methods, that there occurs a diminution of the excitability in the extra-polar catelectrotonic region and an increase in the extra-polar anelectrotonic region, as shown by stimulation with the induced current.

Helmholtz subsequently suggested that the cause of the deviation from Pflüger's law might be the position of the nerve in the uninjured body. As the nerve is in relation with a relatively large amount of well-conducting tissue, the current density must quickly decrease with the distance from the electrodes; whilst, of course, under the polarizing electrode, the current density in the nerve is the greatest; this density, on account of the moist conductors surrounding the nerve, so rapidly decreases that it becomes almost *nil* for the nerve at even a small distance from the electrodes. At a short distance, therefore, from the positive pole the density is so slight that it may be assumed without error that the current now leaves the nerve, or, in other words, that the cathode is to be found at this point. It is to be expected, therefore, that the effects of the opposite pole would be observed only at a short distance from the applied pole. As Erb did not apply the exciting electrode near enough to the polarizing electrode, he obtained, not far from the anode, the phenomena of normal catelectrotonus, and from the cathode those of normal anelectrotonus. Acting on the suggestion of Helmholtz, Erb so arranged the electrodes that the polarizing and exciting currents could be applied either simultaneously or consecutively to the same tract of nerve. By this method of investigation he obtained results which harmonized in the most complete manner with those of physiological experiment, viz., increase of excitability in the catelectrotonic and decrease of excitability in the anelectrotonic regions.

The changes in the excitability of a nerve of a living man and the contractions which follow the closing and opening of the constant current have been thoroughly studied by Waller and de Watteville ("Physiological Transactions of the Royal Society, 1882"). These observers employed a method similar to that of Erb, conjoining in one circuit the testing and polarizing currents. By the graphic method they recorded first the contraction produced by an induction shock alone; and, secondly, the contraction produced by the same stimulus under the influence of the polarizing current. As a result of many experiments, they also demonstrated an increase of the excitability in the polar region when it is cathodic, and a decrease when it is anodic. Following the suggestion

of Helmholtz, that the current density quickly decreases with the distance from the electrodes, they recognize, at the point of entrance and exit of the current from the nerve, two regions,—a polar, having the same sign as the electrode, and a peripolar, having the opposite sign. (See Figs. 10 and 11.) The peripolar regions also experience similar alterations of excitability, though less in degree, according ast hey are cathodic or anodic.

As it is impossible to confine the current to the trunk of the nerve when surrounded by living tissues, as is easily the case when experimenting with the frog's nerves, it is incorrect to speak of either ascending or descending currents. Waller (" Human Physiology," p. 363, 1891), who has thoroughly studied the electrotonic effects of the galvanic current from this point of view, sums up his conclusions in the following words: " We must apply one electrode only to the nerve and attend to its effects alone, completing the circuit through a second electrode, which is applied according to convenience to some other part of the body.

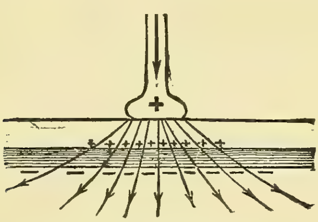

FIG. 10.—ANODE OF BATTERY.

Polar region of nerve is anodic. Peripolar region of nerve is cathodic.

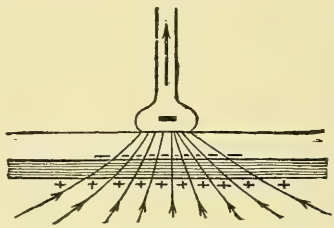

FIG. 11.—CATHODE OF BATTERY.

Polar region of nerve is cathodic. Peripolar region of nerve is anodic.

" Confining our attention to the first electrode, let us see what will happen according as it is *anode* or *cathode* of a galvanic current, Figs. 10 and 11. If this electrode be the anode of a current, the latter enters the nerve by a series of points and leaves it by a second series of points; the former, or proximal series of points, collectively constitutes the *polar* zone or region; the latter, or distal series of points, collectively constitutes the *peripolar* zone or region. In such case the polar region is the seat of entrance of current into the nerve,—*i.e.*, is *anodic;* the peripolar region is the seat of exit of current from the nerve,—*i.e.*, is *cathodic.* If, on the contrary, the electrode under observation be the cathode of a current, the latter enters the nerve by a series of points which collectively constitute a ' peripolar ' region, and it leaves the nerve by a series of points which collectively constitute a ' polar ' region. The current, at its entrance into the body, diffuses widely, and at its exit it concentrates; its ' density ' is greatest close to the electrode, and, the greater the distance of any point from the electrode, the less the current density at that point; hence it is obvious that the current density is greater in the polar than in the peripolar region. These conditions having been recognized, we

may apply to them the principles learned by study of frogs' nerves under simpler conditions. Seeing that, with either pole of the battery, whether anode or cathode, the nerve has in each case points of entrance (constituting a collective anode) and points of exit to the current (constituting a collective cathode), and admitting as proved that make excitation is cathodic, break excitation anodic, we may, with a sufficiently-strong current, expect to obtain a contraction at make and at break with either anode or cathode applied to the nerve, and we do so in fact. When the cathode is applied, and the current is made and broken, we obtain a *cathodic make contraction* and a *cathodic break contraction;* when the anode is applied, and the current is made and broken, we obtain an *anodic make contraction* and an *anodic break contraction.* These four contractions are, however, of very different strengths; the cathodic make contraction is by far the strongest; the cathodic break contraction is by far the weakest; the cathodic make contraction is stronger than the anodic make contraction; the anodic break contraction is stronger than the cathodic break contraction. Or, otherwise regarded, if, instead of comparing the contractions obtained with a sufficiently-strong current, we observe the order of their appearance with currents gradually increased from weak to strong, we shall find that the cathodic make contraction appears first, that the cathodic break contraction appears last, and the formula of contraction for man reads as follows :—

"Weak current........ K. C. C.
Medium current...... K. C. C. .... A. C. C. .... A. O. C.
Strong current........ K. C. C. .... A. C. C. .... A. O. C. .... K. O. C.

"That such should be the normal order of appearance is fully accounted for by the following considerations :—

In the	The Nature of Stimulus is	The Situation of Stimulus is	
K. C. C.	Cathodic	Polar	= Best stimulus in best region ;
A. C. C.	Cathodic	Peripolar	= Best stimulus in worst region ;
A. O. C.	Anodic	Polar	= Worst stimulus in best region ;
K. O. C.	Anodic	Peripolar	= Worst stimulus in worst region ;

which also account for an apparent anomaly, viz., that sometimes the anodic closure contraction precedes the anodic opening contraction, while sometimes this order is reversed. This difference depends upon relative current densities in the two regions, which are determined by the nature of the tissues by which the nerve is surrounded."

Theories of the Electrical Phenomena of Nerves.

The Molecular Theory.—In explanation of the origin of the currents in nerves obtained by uniting the longitudinal and artificial transverse surfaces, du Bois-Reymond assumed, as in the case of muscle, the existence of electro-motive molecules, arranged one behind the other and imbedded in an indifferent conducting medium. These molecules are

supposed to have their positive poles directed toward the longitudinal, their negative poles toward the transverse surfaces. This scheme accounts for the existence of strong but not for weak currents, unless the further assumption be made that the electro-motive force of the molecules diminishes with varying rapidity from the equator. The negative variation of the nerve-current is accounted for on the assumption that the electro-motive force, during the state of excitation, is diminished, or that the molecules themselves become differently arranged, whereby their electro-motive forces become less evident.

The electrotonic currents are explained on the assumption that the molecules have the peripolar arrangement, but are capable of being separated and rotated by the polarizing current. When the current is applied to the nerve, the peripolar molecules become dipolar, and their position becomes such that their negative surfaces are turned toward the positive pole and their positive surfaces toward the negative pole. The molecules thus more or less reversed, according to the strength of the polarizing current, discharge their individual currents in the same direction as the polarizing current, and thus give rise to the electrotonic current. The gradual diminution in the strength of the electrotonic currents in the extra-polar regions is explained on the assumption that the normal tendency of the molecules to maintain their peripolar arrangement gradually asserts itself and resists, in proportion to their distances from the electrodes, the reversing action of the polarizing current.

The Alteration Theory.—According to Hermann, the currents obtained from nerves are not natural, but artificial. When uninjured and in a condition of rest, the nerve is devoid of electrical properties. In order to obtain a current, it is necessary to make a transverse section of the nerve, whereby the cut surface undergoes disorganization and becomes negative to the living substance. The electro-motive forces which then make their appearance at the line of separation between the dead and living tissue—the so-called demarkation surface—give rise to the current which has been termed the demarkation current. The so-called negative variation of the nerve-current Hermann regards as an action current, the result of an electrical opposition between the excited (negative) and the resting (positive) portion of the nerve. Hermann's conclusions as to the origin of the electrical currents in living protoplasm are stated on page 26.

An explanation of the electrotonic currents is based upon an experiment of Matteucci's, who discovered that, if a wire be surrounded with a moist conductor and brought into connection with the electrodes conveying a constant current, additional currents are developed, which are similar to the electrotonic currents of nerves, and which are due to polarization. Hermann subjected these phenomena to a further investigation, and found a yet more striking analogy, which he explained as follows: The current conducted to the sheath tends to equalize itself in

the well-conducting metallic core; but as polarization takes place between the sheath and core, a counter-resistance is established which, adding itself to the ordinary transition resistance, causes the current to escape in longitudinal loops, the extent of which is proportional to the degree of polarization. Electrodes applied to the extra-polar regions will send off parts of these currents, which will have, as shown by the galvanometer, the same direction as the polarizing or constant current. The anatomical structure of the nerve bears some resemblance to the metallic core and its sheath. While there may not be the same difference in conductivity between the nerve-sheath and its axis-cylinder as in the former instance, the fact that the transverse resistance of a living nerve to the passage of a galvanic current is about five times as great as the longitudinal resistance would support the view that the electrotonic condition of the nerve also is developed in consequence of an internal polarization. The internal polarization, moreover, is a property of living nerve-fibre only, as it is entirely absent in the dead fibre. The electrotonic currents are, therefore, due to an escape of the polarizing current.

ELECTRO-DIAGNOSIS.

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Electro-diagnosis is a subject of great importance in many respects, but so difficult and complicated that it is very apt to be neglected in the general study of electro-therapeutics. It may be truthfully said that more knowledge is required to make a correct diagnosis by means of electricity than to use it successfully in the treatment of the case. By its use, however, we often get a knowledge of the probable duration and curability of certain diseases which we never could obtain in any other way.

First of all, it is very important that the instruments used should be carefully constructed and accurately calibrated, so that the results obtained should be as accurate as possible. It is extremely desirable that standard instruments should be adopted, so that different observers can compare the results obtained; but, unfortunately, these do not exist at present. At the Electrical Congress held at Paris in 1881 a standard faradic machine was adopted. In this machine the galvanic generator is a single Daniell cell. The various parts of the machine are as follow:

	Primary Coil.	Secondary Coil.
Length of spool (excluding wooden frame), .	88 millimetres	65 millimetres.
Diameter of spool, ...	36 "	68 "
Diameter of wire, ...	1 "	0.25 "
Number of turns of wire, ...	300 "	5000 "
Layers of wire, ...	4 "	28 "

Resistance, primary coil, about 1.5 Siemens units; secondary coil about 300 Siemens units. Were this machine adopted as a standard for the whole scientific world, and if all our leading makers would adhere rigidly to these dimensions in making faradic coils, then different observers could compare their results with each other. At present, however, there are just as many faradic coils in use as there are makers of electric apparatus, and, therefore, all quantitative comparison is impossible, except between those who happen to possess instruments made by the same manufacturer.

At a recent meeting of the American Electro-Therapeutic Association, held in New York City, committees were appointed to consider the choice and adoption of a standard faradic coil and a milliampèremeter. It is to be hoped that by another year we shall have the standard available for use. It is hardly necessary to say that the use of carefully-standardized instruments, which will enable all who use them to compare

their results, will be of great value to the science of electro-therapeutics. Delicate instruments are very apt to get out of order, and in all large cities there should be standards available to which physicians could bring their instruments at frequent intervals for comparison and correction.

By far the most important branch of this subject is the electrical examination of motor nerves and muscles. This is done in the following manner: Of the two electrodes to be used, one is called the indifferent electrode, and consists of a flat sponge with a metal backing. It is of little consequence where this is placed; but its position is generally the sternum, on account of its convenience and the flat surface which it offers for good contact. The other electrode, which is to be applied to the nerve or muscle, is very much smaller than the former.

Erb recommends an electrode exactly ten square centimetres in surface (the so-called "normal electrode"), so that the density of the current may be accurately calculated. The source of error, however, is in the fact that, although we can calculate with a good deal of certainty the amount of current entering the skin, it is almost impossible to tell what proportion of this enters the nerve which we wish to act upon. It is just this error which forms one of the greatest obstacles to obtaining accurate results in this method.

The conductivity of the skin and subjacent tissues depends upon the amount of moisture they contain, which, of course, may vary from day to day. It is on this account that with the same electrode and the same current a less amount of electricity will reach the nerve at one time than at another, which, of course, will modify the result.

Still another source of error is the variation, both in temperature and in amount, of the water contained in the electrodes themselves. This last error may be minimized by careful attention on the part of the operator.

In order to find the density of the faradic current, the coil-distance in millimetres should be divided by the area of the active electrode in square centimetres. Thus, if the normal electrode of Erb be used, the equation would read:—

$$D = \frac{x \text{ mm. C. D.}}{10^2 \text{ cm.}}$$

If, in place of this electrode, the so-called "unit electrode" of Stintzing be used, the equation would read:—

$$D = \frac{x \text{ mm. C. D.}}{3^2 \text{ cm.}}$$

In view of the fact that it is impossible to tell how much of the electricity enters the nerve, or, in other words, how much of the active electrode is active, this calculation may be dispensed with in the preparation of a practical table for clinical use. In this case the record is kept

simply in terms of the coil-distance. Owing to the lack of standard instruments, it is absolutely necessary for every observer to make his own record for clinical use, and, whenever he makes a test, he must use the same instruments and electrodes that were then employed.

There are, unfortunately, two methods of marking faradic coils, which help to make this much mixed-up subject still more chaotic. One is to have the scale read zero when the two coils are completely closed, and when the current is, therefore, at a maximum. The other—and, in the author's opinion, far more rational method—is to have the scale read zero when the current is at zero.

The writer would offer the following substitute for the present method of notation, which seems to him much simpler and more rational than those now in use: instead of noting the coil-distance in centimetres, to discard the term entirely, and have the scale divided into one hundred equal divisions, to be called degrees of current. When the primary coil is completely uncovered, both the current and the scale are at zero. When the two coils are pushed completely together, one hundred degrees of current are obtained, or the maximum. The coil employed by the writer is marked in this way, and an extensive use of it proves the method to be quite satisfactory.

The following table, showing the average faradic irritability, is from Stintzing:—

Nerve.	C. D. Stintzing.	C. D. American Scale.
Spinal accessory	137.5	12.5
Musculo-cutaneous	135.	15.
Mental branch of facial	132.5	17.5
Ulnar (above olecranon)	130.	20.
Frontal branch of facial	128.5	22.5
Median	122.5	27.5
Facial (main trunk)	121.	29.
Ulnar (at olecranon)	118.5	31.5
Peroneal	115.	35.
Crural	111.5	38.5
Tibial	107.5	42.5
Radial	105.	45.

In this table the figures under the column marked Stintzing show the coil-distance in the scale where 0 C. D. = maximum current. The second column contains the readings of the scale where 0 C. D. = 0 current. In both cases the length of the scale equals one hundred and fifty millimetres.

When testing for faradic irritability, the negative pole of the secondary coil should always be used, since the results vary slightly, according to the pole employed. In testing the galvanic irritability, the same electrodes are used as with faradism.

The instrument used to indicate the amount of current is the milli-

ampèremeter, or milliammeter, of which a different one is made by each manufacturer of electrical apparatus, most of them having defects more or less glaring, either in their adaptation to medical uses or in calibration. They are all supposed to be divided according to the same unit, the milliampère, but there is so much variation between the different instruments that comparison between the results obtained by different men is very far from satisfactory.

Normal Reaction of Nerves and Muscles.

In testing the irritability of nerves and muscles by means of the faradic current the negative pole of the current from the secondary coil is always used, in order that the results may be uniform. The contraction would vary slightly according to the pole used, but the faradic current is not employed in the study of these variations. The galvanic current, being the more constant, is the one used exclusively for this purpose. The irritability may vary in four different ways, forming what is called the normal formula of contraction. If the negative pole be applied to the peroneal nerve, and an electric current sent through it, a contraction will occur,—the strongest obtainable from this current. It is called the cathodal closing contraction (Ca. Cl. C.). If we now apply the anode, or positive pole, to the same spot and close the current, we obtain the next strongest contraction, called the anodal closing contraction (An. Cl. C.). If this current be now broken or opened, we have a still weaker response from the muscles known as anodal opening contraction (An. O. C.). Finally, if we apply the negative pole again and open the current, we shall have the weakest contraction of all,—cathodal opening contraction (Ca. O. C.).

The following table, prepared by Luvandowski, exhibits the formula for three nerves. The figures in the columns denote the amount of current, expressed in milliampères, required to cause contraction of the muscles which the nerves supply. The testing electrode had a superficial area of ten square centimetres,—the " normal electrode " of Erb :—

	Ulnar Nerve.	Radial Nerve.	Median Nerve.
Ca. Cl. C.	1.0	1.8	0.8
An. O. C.	2.5	3.7	1.0
An. Cl. C.	1.3	3.5	0.9
Ca. Te.	4.3	7.8	4.0
Ca. O. C.	4.9	9.0	6.0

It is to be understood that the contractions produced are just sufficient to be distinctly visible to the eye. The greatest care must be used to have the active electrode accurately localized upon the part whose reaction it is desired to test. The only way this can be accomplished is thorough anatomical knowledge of the parts, combined with skill and

experience in the use of the method. Another rule of value to follow is: always use the same method and keep to the same order in making these examinations. If this is done and the same instruments are used, with the same electrodes soaked to the same degree with water at the same temperature, then the results obtained should be susceptible of comparison with others, and be able to give us valuable information as to the healthy or diseased condition of the parts. In making these examinations it must be borne in mind that the electric stimulus is very fatiguing to nerves and muscles, and therefore, if the same part be examined too often, the final result may be deceiving.

Changes in Electrical Irritability.

The electrical irritability of nerves and muscles may differ in two ways; that is, either in quantity or quality. As to quantity, it may be either increased or diminished. Increased irritability means that a smaller amount of current is required to produce contraction than under normal conditions. This condition is met with in tabes dorsalis and tetany. Diminished irritability is just the reverse of the former condition. It is found in many affections of the motor apparatus, as myelitis, spastic paralysis, multiple sclerosis, brain-tumors, multiple neuritis, writers' cramp, etc.

Increased or diminished irritability is generally the same for both currents. Cases are occasionally found, however, where one is increased and the other diminished. Where single groups of nerves are affected, or where the disease is confined to one side of the body, as in cases of hemiplegia, the well side should always be examined first, and then the affected side. In this manner variations from the normal are readily detected. Where the affection is bilateral it is more difficult to arrive at a satisfactory result for lack of any part of the individual to be used for comparison. They may be compared with the average normal irritability which the experimenter has found out by previous observations, and this is the ordinary method of procedure.

Another plan has been devised by Erb, which it is well to be acquainted with. It may be of use on occasion, in order to verify the results obtained in the ordinary way. It consists in determining the irritability of four nerves in different parts of the body, and thus finding out their relative value. He lays great stress upon the importance of first finding out the relative resistance of the parts, for upon this depends the amount of electricity which enters the body, and therefore the degree of contraction produced.

Every change in the relative value of the resistance of the parts has a direct effect upon the importance to be given to the results obtained in testing the irritability. Suppose, for example, that in a certain case both peroneal nerves were found to be affected by currents much weaker than ordinary. If the resistance was normal, this would show that the

irritability of these nerves was increased. If the resistance of the parts was found to be greater than normal, it would indicate that the irritability of these nerves was even greater than was at first supposed. If, on the contrary, the resistance was less than normal, it would account for the apparent increase in the irritability, and might lead to the conclusion that it was really no greater than it should be.

In making these examinations the following four nerves should be chosen: The frontal branch of the facial nerve,—*i.e.*, that which supplies the frontalis and corrugator muscles; the spinal accessory, which supplies the trapezius muscle; the ulnar nerve in the arm above the elbow; and the peroneal nerve in the leg just above the capitellum fibulæ. By means of a fine electrode these four points are carefully sought out, and with the negative pole of the faradic current contractions are obtained at each of them, and the results noted in coil-distance. The galvanic current is now made use of, and the amount of current which a fixed number of cells (10 to 12) would give at each of the four points is also noted. The same apparatus is used throughout the examination, and the same method employed; that is, the negative pole is used for the active electrode, while the positive pole rests upon the sternum.

The following tables are examples of what has just been described. The figures in the first two columns express the irritability of the nerves on the two sides of the body. Those in the last two columns show the amount of current which a constant electromotive force (10 cells) gives at each of the four points of application. They express, therefore, the relative amount of resistance at these points:—

1. Healthy man, aged 38; artisan.

	Coil-Distance in Millimetres. Minimum Contraction.		Deflection of Galvanometer with 10 cells. C. R., 150.	
Frontal nerve	Right, 165	Left, 166	Right, 18°	Left, 19°
Spinal accessory	" 172	" 177	" 16°	" 15°
Ulnar nerve	" 150	" 158	" 6°	" 6°
Peroneal nerve	" 160	" 163	" 7°	" 9°

2. Healthy man, aged 24; laborer.

Frontal nerve	Right, 195	Left, 192	Right, 17°	Left, 17°
Spinal accessory	" 187	" 182	" 10°	" 9°
Ulnar nerve	" 175	" 185	" 6°	" 10°
Peroneal nerve	" 180	" 180	" 5°	" 5°

It is to be observed that the force of the galvanic current in these tables is noted not in milliampères, but in the degrees of the scale of an ordinary galvanometer. The difference between a galvanometer and a milliampèremeter is that in the former instrument the degrees are arbitrary gradations, while in the latter they represent the now universally

recognized unit of quantity,—the milliampère. This is of little consequence, however, since it is not the absolute values that are desired here so much as the relation between them.

It has been found, from numerous observations of this kind, that the reactions for the two sides of the body are almost exactly the same. The reactions of the ulnar and peroneal nerves are also very similar, while the frontal nerve shows itself a little less sensitive and the accessorius a little more sensitive. The great importance of these three data lies in the fact that, being simply expressions of relative value, they are just as true for one instrument as for another, and may be made use of when testing the irritability of the nerves, without regard to the apparatus employed.

Qualitative Changes in Electrical Irritability.

The irritability of nerves and muscles may be increased or diminished, as already described; but, in addition, we may also have changes in the character of the contractions produced. These changes, taken together, are known as the reaction of degeneration.

Reaction of Degeneration.

It should be explained just here, for the sake of clearness, that in certain old cases of paralysis—as, for example, the facial and also the infantile form—there is absolute degeneration of both nerve and muscle; that is to say, these parts lose their characteristic structure and become simple bands of fibrous tissue, which, of course, give no reaction either to the faradic or galvanic currents. This absence of reaction has nothing to do with the so-called reaction of degeneration. The typical form of the reaction of degeneration occurs about as follows: After a slight increase in the electrical irritability, there begins a decrease of the same in the affected nerve until about the end of the second week, when it completely disappears, both for the faradic and galvanic currents. All voluntary movements are now impossible.

As to the muscles supplied by the affected nerve, their irritability to the faradic current is gradually lost, but to the galvanic current it slowly increases. In certain cases the irritability to the galvanic current is so greatly increased that contractions are produced by the electrical irritation of the well side. The mechanical irritability of the muscles is also increased so that a light tip with the end of a lead-pencil will often cause them to contract.

The most characteristic sign of the reaction of degeneration is what is known as the "sluggish contraction" (träge zuckung). When galvanism is applied to a healthy muscle, the resulting contraction is as quick as lightning (blitzartige). When the reaction of degeneration is present, however, the galvanic current, even if strong, never produces the

lightning-like contraction of health, but, in its place, a slow, lazy contraction. Changes in the normal formula of contraction also occur early in the process of degeneration. The An. Cl. C. gradually increases in strength, and may even become finally stronger than the Ca. Cl. C. The Ca. O. C. also increases in strength. After a few weeks, the increased galvanic irritability disappears, while the changes in the formula and the sluggish contractions remain.

The first sign of regeneration in the affected nerves and muscles is the return of the muscular tone, whereby they are seen to hold their own better against the constant pull of the antagonizing muscles. Voluntary motion next becomes possible, though the muscles are very weak and soon tire out. Then the nerve itself becomes susceptible to electrical stimulus, although it remains for a long time below the normal irritability. Finally, abnormalities in the formula of contraction disappear from the muscles, along with the sluggish contractions.

The pathological changes occurring in the muscles and nerves which exhibit the reaction of degeneration are as follow: In the early days of the process the medullary sheath undergoes granular degeneration. The axis-cylinder softens down to a homogeneous protoplasmic mass, and the nuclei in the white substance of Schwann proliferate. There is formed a large amount of new connective tissue, which grows into the nervous matter in all directions, and finally produces a regular cirrhosis of the nerves. At the point of injury to the nerve, if there has been one, a circumscribed traumatic neuritis occurs. The regeneration takes place by means of trophic influences. First the seat of injury is bridged over by what might be called a sort of protoplasmic callus. The repair of the nerve begins at the periphery. The pale, narrow bands which represent the nerve-fibres gradually surround themselves with a medullary sheath, and the continuity of the separate fibres is restored. The newly-formed interstitial connective tissue remains permanent, however. The muscular fibrillæ undergo simple degeneration, or, at most, there is but a small amount of adipose formation.

If regeneration does not take place, there may be complete disappearance of the muscular tissue. The muscular nuclei increase, and collections of cells form in the interstitial connective tissue, which lead to hyperplasia and cirrhosis of the same. In incurable cases the muscle is reduced to a thin, fibrous cord, with only here and there traces of muscular tissue. The processes of degeneration in the nerve and the interruption of continuity explain quite satisfactorily the various phenomena as seen. It must be said, however, that, as regards certain details, it is to a great degree speculation. The increased irritability of the muscles to the galvanic current is owing, according to Gessler, to irritative processes within the sarcolemma. The rapid loss of faradic irritability of the muscles, as well as the change of the normal formula of contraction, is due to chemical changes in the muscle. The decrease

of the galvanic irritability, later in the course of the disease, is due to the progressive increase in the muscular atrophy.

Atypical Forms of the Reaction of Degeneration.

It must not be supposed that all forms of degeneration follow the typical course just described. Between normal reaction of nerve and muscle and fully-developed reaction of degeneration we may have all degrees of change. Stintzing divides the reaction of degeneration into four different grades, as follows: 1. Highest grade. Reaction of degeneration, with total loss of irritability of the nerve. Seen in peripheral paralysis, chronic poliomyelitis, and progressive bulbar paralysis. 2. High grade. Reaction of degeneration, with partial irritability of the nerve. Seen in peripheral paralysis. 3. Middle grade. Reaction of degeneration, without loss of irritability, but with sluggish contractions to both currents. Seen in peripheral paralysis, chronic poliomyelitis, and after nerve-stretching. 4. Lower grade. Reaction of degeneration, with prompt contraction from electric irritation of the nerve (partial reaction of degeneration). Seen in peripheral and diphtheritic paralysis, progressive bulbar paralysis, and atrophic spinal paralysis; also after nerve-stretching.

These four principal groups do not exhaust all the varieties and modifications of this condition. The same nerve-trunk may present complete reaction of degeneration in one part of its course and the partial form in another portion. Partial reaction of degeneration may be found in a nerve, and later on in the course of the disease the degeneration may become complete. Finally, the galvanic current may produce a prompt reaction, while the faradic current causes sluggish contractions.

As to the muscles, there are certain peculiar cases where one part of a muscle is degenerated, another portion still further degenerated, while still other portions may have escaped entirely. Such cases present a diminished irritability of the nerve to both currents, while the muscle itself shows every possible variation, both in the form and intensity of the contractions produced.

The Electric Reaction of Myotonia Congenita.

As is well known, this disease consists in a remarkable stiffness and rigidity of the muscles after rest. With continued motion the limbs gradually regain their normal flexibility. Energetic contraction of a muscle produces a condition of tonic spasm, lasting from ten to thirty seconds. In these cases the nerves show a normal reaction to both the faradic and galvanic currents. It is very different with the muscles, for they exhibit to both currents a greatly-increased irritability. Even moderate faradic currents produce a continuous muscular contraction.

If the galvanic current be used, there is observed a remarkable sluggishness and duration of the contractions produced. These contractions often have the result of causing deep hollows or ridges in the muscles, with corresponding slow movements of the limbs. If the current be allowed to flow stabile through a muscle, a remarkable phenomenon occurs. There arise regular rhythmical contractions, which start from the negative pole and travel toward the positive. This phenomenon is best produced when the electrode is placed not directly upon the muscle itself, but in the immediate neighborhood of its point of insertion. These contractions may occur in any of the voluntary muscles, and form, therefore, an important factor in the diagnosis of myotonia congenita.

Electrical Examination of the Eye.

The electrical examination of this organ has been made use of by various observers, and found to be of considerable assistance in the diagnosis of the diseases affecting it. It is performed in the following manner: A flat sponge-electrode is placed at the back of the neck, on the side corresponding to the eye to be examined. The reason of this is that if the sponge be placed in the median line both eyes are apt to be affected, on account of the diffusion of the current. The active electrode should be placed directly upon the closed lids of the eye to be examined. The ordinary small, round hand-sponges which come with every battery do very well for this purpose. Both eyes should be closed during the examination, and it is much better to have them closed a few minutes before, so that the retina may become entirely free from usual impressions.

Erb recommends that the examination be conducted in a darkened room, which is an excellent idea. The quantitative estimation of optic irritability can never be of much value until the milliampèremeters which physicians have at their command are more satisfactory. Even if the scales of the instruments are correct, they are generally so small that slight variations of the needle, such as fractions of a milliampère, are hard to appreciate. The current necessary to produce the reaction of light in the normal eye is about one milliampère. It is evident, therefore, that the instrument that is used in these experiments should have a scale so large that halves and quarters of a milliampère can be read off with ease and accuracy.

The normal reaction of the eye, the colors, etc., will be found fully set forth in the chapter on electro-physiology. As to the electro-diagnosis of diseases of this organ, there yet remains much to be found out, and it offers a most inviting and fruitful field to the specialist in ophthalmology.

As mentioned above, with a current of one milliampère, or thereabouts, a distinct sensation of light should be perceived, as well as color. The difference between the positive and negative poles ought also to be discernible by the patient. In examinations of the eye, as well as of all

the special senses, great patience and skill are necessary. It is also desirable that the weakest possible currents should be employed, in order to avoid the production of headache. The most important variations from the normal are absence of the perception of color, diminished sensibility to light, and the loss of the ability to distinguish between the poles. These conditions generally indicate the presence of neuritis optica, or atrophy of the optic nerve. It may be mentioned, also, that it is possible to obtain reaction of the iris by means of the faradic current. In order to do this, the pole must be applied directly to the cornea, and, on this account, it can only be done in cases of ether narcosis or unconsciousness from some other cause.

Electrical Examination of the Ear.

The early methods for examining this organ generally required that the external meatus be filled with water or a solution of salt. This was found to be quite objectionable for many reasons, and is now for the most part abandoned. Among the various methods in use, the author would recommend, for the active electrode, the ordinary small, round sponge which comes with all batteries. The indifferent electrode should be a flat sponge, which may be slipped beneath the collar at the back of the neck.

The normal formula of reaction of the auditory nerve may be found fully explained in the chapter on physics. In examining for the pathological changes in the auditory nerve, special skill and great patience are required, since the results obtained are often very misleading. The most frequent variation from the normal is what is known as simple galvanic hyperæsthesia. In this condition the nerve is so sensitive that currents so weak as hardly to stir the needle of the milliampèremeter will produce a distinct sensation of sound. Moreover, the sounds which are produced are of very marked character,—whistling, singing, or ringing,—and they last for a much longer time than ordinary. In spite of this excessive sensibility, the normal formula, as explained in a previous chapter, remains unchanged.

Cases frequently occur, however, where, in addition to the hyperæsthesia, we may have also anomalies in the formula. For example, there may be present a ringing sensation with An. Cl. and An. D. If the current is strengthened, the same ringing may occur with Ca. O. Moreover, these sounds so produced have a distinctly pathological character, which distinguishes them from those brought out by the galvanic current in the normal ear.

All varieties of change from the normal formula may be found in different diseases of the ear, without any hyperæsthesia or increase in the sensibility. The anomalies are generally seen in chronic diseases of long standing. They are supposed to owe their origin to injuries of the skull, or to disturbed nutrition. Another anomaly is known as torpor

of the auditory nerve. Owing to the difficulty of obtaining the reaction, even under normal conditions, the diagnosis of torpor of this nerve should be made with great caution. In such cases the resistance should always be determined, in order to be sure that its increase may not account for the torpor. This anomaly is met with in serious and incurable affections of the auditory apparatus.

The Sense of Taste.

This sense is best examined by means of an instrument invented by Neumann. It consists of a long stem carrying two wires isolated from each other and ending in little balls, which form the two poles of the current. By means of this electrode any part of the tongue or inside of the buccal cavity may be examined and the sensations of taste noted. As yet no practical application has been made of this method to the diagnosis of disease. As to the reaction of the nerves of smell to the electric current, nothing of any moment is yet known.

Examination of Common Sensation.

It must be acknowledged that the electrical examination of sensory nerves is not by any means as important as that of the motor nerves. It is, however, a more accurate, and at the same time more convenient, method than the various others employed for the purpose. Up to the present time we know of but two variations from the normal to be found by this method: hyperæsthesia, or increased sensibility; and anæsthesia, or decreased sensibility. In testing the condition of the sensory nerves, the active electrode is so made as to present a great many points of contact. Erb devised one made of a large number of wires fastened together so that their ends presented a smooth surface. Modifications of this form have since been made, but all with the same end in view,—of obtaining as many points of contact as possible.

The method of finding out the sensibility of the surface of the body is as follows: The electrode just described is connected with the faradic coil and placed upon the portion to be examined. The other, or indifferent, electrode may be placed anywhere. The coils are now brought together until a very slight sensation is felt, and the coil-distance noted. They are now pushed still farther on until a painful sensation is produced, and the coil-distance again noted. From numerous observations averages are obtained for different parts of the body. These averages, once found, enable the observer to detect deviations from the normal. Such deviations occur in various diseases of the brain, spine, and peripheral nerves.

Bernhardt has tested the reaction of cutaneous sensibility, and finds that it varies in different areas or zones of the body. He divides the surface of the body into nine zones, as follow:—

1. Tongue zone (tip of tongue, palate, tip of nose).
2. Face zone (eyelids, gums, red surface of lips, cheek).
3. Forehead zone (forehead, cutaneous surface of lips).
4. Shoulder zone (shoulder).
5. Trunk zone (sternum, nape of neck, spine, arm, forearm, buttock, occiput, front of neck).
6. Thigh zone (sacrum, thigh, dorsum of foot).
7. Hand zone (back of hand, leg, ball of fingers).
8. Patellar zone (patella).
9. Digital zone (tip of toes, palm of hand, sole of foot).

The average minimum coil-distance of sensation and of pain for these various regions is given in the following table :—

Zones.	General Electro-sensibility of the Skin. Average Min. C. D.	Painful Electro-sensibility of the Skin. Average Min. C. D.
1. Tongue zone	166. millimetres.	136.7 millimetres.
2. Face "	150.5 "	130.5 "
3. Forehead "	144.5 "	128. "
4. Shoulder "	137. "	112.5 "
5. Trunk "	128. "	110.8 "
6. Thigh "	122.1 "	99.1 "
7. Hand "	116. "	92.8 "
8. Patellar "	111. "	88. "
9. Digital "	114.5 "	67.8 "

As the difference in the resistance of the skin at various points may cause an error in the result, Erb recommends that this resistance be found in each case by means of the galvanic current. He found that, in some cases, differences in the sensibility at corresponding points on opposite sides of the body could be explained by this difference of the resistance to the current.

The electrical examination of common sensation is of special interest and value in cases of locomotor ataxia. The sensibility of the whole surface of the body will often be found very much decreased. The sensibility to pain is generally affected in proportion to the general sensibility, but in certain cases there will be absolute and complete analgesia, even when the coils are pushed entirely together so as to give the strongest possible current. In unilateral affections, where one side of the body remains comparatively normal, as, for example, in cases of injury, the difference in the farado-cutaneous sensibility on the two sides can often be clearly and beautifully brought out.

Sensation of Internal Organs.

Attempts have been made at various times to investigate the sensibility of the internal organs, but, so far, without very material result. Duchenne investigated the peculiar feeling produced in a muscle by the passage of an electric current through it, but did not arrive at any very important conclusions.

CATAPHORESIS, ANODAL DIFFUSION, ELECTRICAL OSMOSIS, OR VOLTAIC NARCOTISM.

By FREDERICK PETERSON, M.D.,

NEW YORK.

From a medical stand-point we understand by cataphoresis the introduction of medicaments by means of electricity into the body through the skin or mucous membranes. It seems to be a purely physical process, and has nothing to do with electrolysis. As is well known, particles of carbon in the Davy arc-light are carried from the positive to the negative pole.

Physically and not physiologically speaking, it is almost certain that electrical endosmosis is a mechanical and not an electrolytic effect, for two reasons: first, the action will show itself in any single solution whenever a porous partition, such as plaster of Paris, stoneware, etc., is inserted in the path of the current, even when no electrolysis is taking place,—that is, no decomposition; and, secondly, because the phenomenon may be stated as follows: Whenever a capillary tube containing liquid sustains a difference of potential between its extremities, liquid is transferred through the tube toward the cathode. The fact that the flow is proportionate to the difference of potential with a given current is equivalent to the usual statement that the effect increases with the resistance of the septum, because, the greater the resistance, the greater the difference of pressure that a fixed current will establish between the surfaces. The converse of the proposition also holds good; that is, whenever liquid is forced through a capillary tube, a difference of potential is set up between its ends. Thus, a flow of liquid through a plug of plaster under hydrostatic pressure will set up a difference of potential opposite to the direction of flow between the bounding surfaces. This phenomenon is commonly called capillary electro-motive force. The cause is not known; it is some definite mechanical or dynamic action, and Helmholtz has given a working theory, but it will probably be understood only when electricity is understood. This is the view of Kennelly, Lewandowski, and myself.

The following facts explain the character of the process in a clearer and more popular form: If two compartments separated by a membrane are filled with a fluid and in each an electrode is placed, there is a streaming of the fluid through the septum in the direction of the galvanic current,—that is, from the positive to the negative pole,—so that in the

course of time there is an increase of fluid in the negative compartment. This osmosis, as is well known, occurs naturally without the use of electricity between two dissimilar liquids, the direction of the osmotic current being from the lighter to the denser liquid. But if the anode is placed in the denser liquid and the cathode in the lighter, this natural osmotic current is not only overcome, but reversed. Du Bois-Reymond termed this the cataphoric action of the constant current. This streaming movement is analogous to that taking place in the semi-solid sarcous substance of muscle when subjected to the constant current, and observed under the microscope,—a visible flowing of the contents of the muscular fibre from the positive to the negative pole, causing a swelling of the fibre at the negative end. This is called Porret's phenomenon in living muscle. W. Kühne has experimented on this.

Now, it has been found that the skin of animals is permeable to drugs. The degree of absorption varies in different animals, and depends upon the quality of drug employed and the manner of its application to the skin. Thus, the skin of the frog absorbs water or watery solutions rapidly (Guttman), while that of man does not do so at all, because of the fat normally present upon the epidermis and in the pores. Solutions containing alcohol, ether, or chloroform, by removing the fat, render absorption easy (Parisot). All substances which are volatile and corrode the epidermis, like carbolic acid, are readily absorbed (Röhrig). Watery solutions striking the human skin in a finely-disseminated spray may reach the interior of the body, probably by penetrating the interstices of the epidermis (Juhl).

Massage, in connection with cutaneous medicaments, causes easy absorption by forcing the particles into the pores. Wherever the epidermis is removed, as by an abrasion, burn, or blister, the transference of substances through the skin is rapid.

In 1863 Quincke experimented with a minute column of fluid in a fine capillary tube, at either end of which platinum wires were introduced. When the lower end was made the anode and the current turned on, there was a motion in the liquid in the upward direction. Porous membranes, then, may be looked upon somewhat as a large number of capillary tubes in juxtaposition, and through these the substances in solution are driven by the electric current as it flows from the anode to the cathode. Not only the galvanic current may be used for the purpose of introducing drugs, but also the current from the static machine; but no conclusive experiments have as yet been made with static electricity.

A very pretty experiment, devised by Ehrmann, of Vienna, may be used to demonstrate the cataphoretic power of the anode: Take two similar glass vessels, with zinc electrodes at the bottom, and filled with a very weak solution of methyl-blue. Insert the hands, one in each, and cause 10 to 20 milliampères to pass for from five to ten minutes. The hand in the anode vessel will be covered with blue spots.

The cataphoric action of electricity has often been made use of experimentally to introduce drugs into the system through the skin. The anode, moistened with a solution of strychnine, has been applied to the skin of a rabbit, the cathode being placed upon any indifferent spot, and in a few minutes the animal has died from strychnine poisoning (H. Munk). In man, quinine and potassium iodide have been thus introduced and subsequently detected in the urine (Landois and Sterling, "Physiology," p. 489).

Efforts have been made more particularly, however, for the purpose of producing a local anæsthesia by the use of electro-chemical osmosis. As far as I can learn, the first investigator in this direction was Dr. B. W. Richardson, who wrote two articles on "Voltaic Narcotism" in 1859.[1] He began experimenting in October, 1858, by producing a local anæsthesia with a solution of morphine on the anode. Then, with a simple galvanic current and with tincture of aconite on the positive pole, he brought about complete anæsthesia of a rabbit's ear, after trying in vain to do so with the current alone. After this he made the following solution:—

℞ Tinct. aconiti, ... ℥iij.
Ext. aconiti alc., ... ℈j.
Chloroformi, ... ℥iij.—M.

One-third of this was put on a sponge, which was wrapped around the upper part of the hind-leg of a dog, after shaving it, and attached to the positive pole, the other pole being applied to the ankle. In eleven minutes there was complete anæsthesia to transfixion with pins anywhere between the electrodes. A minute later a subcutaneous section of the tendo Achillis was made without pain. At the end of an hour the limb was amputated about an inch below the knee without a wince until the bone was sawed, when the animal screamed once, but it was not known whether this was from pain or terror. There was no pain in the subsequent manipulations. Twenty minutes later the animal ate heartily and walked about unconcernedly upon three legs. The wound healed by first intention. Subsequently, transferring his experiments to mankind, he painlessly removed a one-inch nævus from the shoulder of a ten-week-old babe, after half an hour's voltaic narcotism with 5 minims each of chloroform and tincture of aconite. Then, in five cases of extraction of teeth, a fine anode wound with cotton soaked in the same solution of chloroform and aconite produced complete anæsthesia in ten minutes. Afterward a new method was used successfully in a case of strangulated hernia in a man; in one of tumor of the shoulder, of the size of an orange, in a woman aged 47 years; and in one of staphyloma of the cornea. Equal parts of chloroform and tincture of aconite were used in all, and the duration of the narcotic process varied from half an hour to an hour.

[1] Med. Times and Gazette, February 12 and June 25, 1859.

It is needless to say that Richardson's articles roused a storm of opposition in the medical press of England and the Continent. The ground taken by his opponents may be illustrated by the conclusions of A. Waller,[1] which are as follow: Insensibility from so-called voltaic narcotism is produced solely by the local absorption of the chloroform-and-aconite mixture. Anæsthesia is produced with equal efficacy by the mere topical application of the narcotic mixture without the electric current. The procedure is, in itself, painful, and the result is inflammation and disorganization of the skin.

It is to be regretted that Richardson himself subsequently abandoned the position he had taken with regard to voltaic narcotism.[2] The subject slumbered for more than twenty-five years, and has only of late years been revived, or rather re-discovered, for Richardson's articles had, in the meantime, been so completely forgotten that no reference had been made to them anywhere until I called attention to them in my first article in 1889. Wagner[3] re-introduced the matter to the profession in 1886 by a short note on the possibility of cocaine anæsthesia with the galvanic current, but without definite experiment. But Adamkiewicz has written more fully upon this subject of late than any one else. His first article, in 1886, described what is known as his diffusion electrode,[4] with which he professed to introduce chloroform into tissues and produce local anæsthesia. He found chloroform would evaporate too rapidly from the ordinary sponge-electrode, and hence devised this new instrument. It holds three cubic centimetres of fluid in a hollow brass cylinder, the bottom of which is of porous carbon. Over the carbon bottom a piece of moistened linen is stretched to prevent burning when in contact with the skin. This instrument is made the anode, of course, and applied to painful spots in neuralgia with a 3- to 5- or 7-milliampère current. He professed to obtain a gradual anæsthesia with disappearance of pain, and had employed the method with chloroform in rheumatic pains and neuralgias of the intercostal and trigeminal nerves,

This revival of Richardson's discovery was again met by strong opposition and criticism. Paschkis and Wagner[5] maintained that chloroform was almost a complete insulator and did not conduct at all; that, though anæsthesia was produced, it was solely due to contact of the chloroform with the skin, and that the gradual disappearance of the chloroform from the electrode, noticed by Adamkiewicz and ascribed by him to cataphoresis, was nothing but an evaporative phenomenon.

Adamkiewicz replied that, though a poor conductor, chloroform did conduct, and that anæsthesia was produced in four minutes, first to temperature and then to pain; that with a strong current deep slough-

[1] Med. Times and Gazette, March 19 and July 30, 1859. See, also, views of J. Althaus, Wein. Med. Woch., ix, 1859, p. 433.

[2] Med. Times and Gazette, February 3, 1866.

[3] Wiener Med. Presse, 1886, S. 212.

[4] Neurolog. Centralbl., Bd. v, S. 219–497.

[5] *Ibid.*, Bd. v, S. 413.

ing could be produced in a few minutes, which chloroform alone could not induce for hours, and he was able to show cataphoresis with the galvanic current in a rabbit's ear by staining chloroform with gentian violet. Afterward he reported three cases of neuralgia, at the Sixth Congress für innere Medecin,[1] relieved by his method, with a 1- to 7-milliampère constant current, where other means had failed to do any good.

Lumbroso and Matteini[2] have employed chloroform with ordinary electrodes and 10 to 12 milliampères in neuralgia, always with great success in relieving pain; whereas the current alone, without chloroform, produced no result.

Dr. J. L. Corning[3] has reported some experiments of his with cocaine cataphoresis. He tried a 5-per-cent. solution with the anode and produced a slight effect. He then perforated the skin by means of the Baunscheidt needles, and was able to produce anæsthesia with a 2½-per-cent. solution of cocaine on an ordinary sponge-electrode. He reported, however, no cases.

Dr. Reynolds,[4] of Chicago, published, in 1887, an article upon the use of cocaine in 2- to 20-per-cent. solutions with the anode, in his dermatological practice for small cutaneous operations and for the electrolysis of hair-roots. He also used voltaic narcotism in one case of tooth-extraction, as had been done by Richardson just thirty years before.

My own early experience with electric cataphoresis extended over many months of time in 1888, and my experiments numbered much over a hundred, about a fourth of which I reported in detail in 1889. Actuated by the great diversity of opinion among the investigators I have quoted, I began at the foundation, in order to demonstrate to my own satisfaction the actual facts in a scientific manner. My early trials are here reproduced:—

Experiment No. 1. *Uselessness of the Adamkiewicz Electrode.*—Barrett 50-cell chloride-of-silver battery. Placed three cubic centimetres of a 4-per-cent. aqueous solution of Merck's cocaine in the Adamkiewicz electrode (diameter, four centimetres) and made it the anode. Applied this to the skin over first interosseous muscle, between the thumb and index finger of the left hand, an ordinary sponge-covered negative electrode five centimetres in diameter being placed in the palm of the same hand. Both sponge and linen over the two electrodes were first well moistened. The current from eighteen cells was used for three minutes. No change of any kind in sensibility.

Experiment No. 2.—Same details as in No. 1, but current contact for five minutes. No change in sensibility.

[1] Neurolog. Centralbl., Bd. vi, S. 238.
[2] "Sulla cataforesi elettrica," La Riforma medica, July and November, 1886.
[3] New York Med. Jour., November 6, 1886.
[4] Jour. of the Amer. Med. Assoc., August 20, 1887.

Experiment No. 3. *Current Painful.*—Same details as in No. 1, except that twenty cells were used for three minutes, causing severe prickling and burning sensation at once. Very feeble anæsthesia to touch and slight hyperalgesia on pricking, possibly due to the pressure on the terminal sensory filaments by the intense congestion produced by the anode. Sensibility normal three minutes later.

Experiment No. 4.—Same details as in No. 3, but current applied for ten minutes. Exactly the same sensory disturbance as in last experiment.

Experiment No. 5. *Defects in Adamkiewicz's Electrode.*—The Adamkiewicz electrode was replaced by an ordinary sponge-covered metal electrode two centimetres in diameter, soaked in the 4-per-cent. solution of cocaine. Details same as in No. 3. Current applied for six minutes. Could then prick with a needle until bleeding occurred (in a spot one centimetre in diameter, where cocaine had been applied) without its being felt, and there was also complete anæsthesia to touch and temperature. This anæsthesia lasted ten minutes. Investigating into the cause of this remarkable difference in results, I found that the electrode of Adamkiewicz was absurdly faulty in construction. The metal cylinder, with its carbon bottom, was a piece of inexcusable stupidity. As the electric current travels where there is least resistance, it is evident to the merest tyro that the whole current will traverse the metallic part of this electrode, and not a vestige pass through the fluid and carbon disc, when it is applied closely to the skin.[1] The resistance of chloroform amounts to billions of ohms. I consequently abandoned any further use of this instrument for therapeutic purposes; but subsequent experiment with it showed very clearly that its inventor produced local narcosis to a certain extent. The law should not be lost sight of that the amount of electrical osmosis grows with the resistance of the fluid acted upon. Hence the enormous resistance of chloroform adds to its cataphoric power. The electrode of Adamkiewicz doubtless did carry chloroform into the tissues, notwithstanding the criticisms of Wagner and Hoffman; for the bottom, when in use, is covered with moist linen, and no doubt a thin layer of chloroform would get between the circular metallic rim and the skin. Hence both Adamkiewicz and Hoffman are right in some of their statements and wrong in others. My own experiments with chloroform sufficiently attest this. Thus, as the current passed through the metallic rim, it met with an infinitesimal quantity of chloroform and transferred it through the skin, producing some narcotic effect. But evidently Adamkiewicz was very much deceived in his instrument, for he believed the contained liquid would pass through the carbon disc, and actually thought he detected an appreciable diminution in the quantity of liquid held by his instrument.

[1] I see that this has also been quite recently pointed out by J. Hoffman (Neurolog. Centralbl., November 1, 1888).

Experiment No. 6. *No Anæsthesia with Cocaine Alone.*—This experiment was undertaken for the purpose of ascertaining if the electric current really had any effect in hastening anæsthesia. A 4-per-cent. solution of cocaine was applied to the skin of the dorsal surface of my left hand for twelve minutes by holding the open mouth of the bottle containing the solution against it. The skin surface in contact with the solution was one centimetre and a half in diameter. No anæsthesia of any kind was produced.

Experiment No. 7. *None with 10-per-cent. Solution.*—For same purpose as No. 6. Soaked a metal sponge-covered electrode, two centimetres square, in a 10-per-cent. solution of cocaine and applied to skin over first interosseous of my left hand for ten minutes without current. No anæsthesia whatever produced.

Experiment No. 8. *No Anæsthesia with Current Alone.*—Same electrode as in No. 7 to same place. A large sponge-covered wire-netting cathode, some eight by twelve centimetres square, in the palm of same hand. Sixteen cells of a Grenet battery for six minutes without cocaine. No anæsthesia whatever.

Experiment No. 9. *Current and Cocaine Together Cause Marked Anæsthesia.*—Same electrodes and application as in No. 8, but with 10-per-cent. solution of cocaine on the anode. Contact for five minutes with sixteen cells of Grenet battery. Complete anæsthesia to touch, pain, and temperature lasting over an hour in surface in contact with anode. It is known that the anode normally paralyzes the vasomotor nerves, producing congestion and œdema, while cocaine has the opposite effect, contracting the capillaries ; but, when applied together, the normal electric effect outbalances that of cocaine, and the part under the anode remains congested. The current itself with this strength is somewhat painful at first at the anode, but as anæsthesia appears the pain gradually diminishes and ultimately disappears.

Experiment No. 10.—Exactly same details in every respect as in No. 9, but applied to the hand of Dr. J. A. Booth instead of my own. Same anæsthesia as on myself. Repeated this the next day on Dr. Booth for seven minutes, with same result. The anæsthesia in these short applications is always limited to the area of the anode.

Experiment No. 11. *No Effect with Cathode.*—Exactly same electrodes and application as in No. 9. Same number of cells, but commutator reversed so that the 10-per-cent. solution of cocaine was on the cathode. Contact of current for five minutes. Result: continual increase of pain at spot under cathode and no anæsthesia whatever,—the very opposite effects produced by the anode.

I had now satisfied myself that a watery solution of cocaine alone, applied to the skin, or upon the cathode with a strong continuous current, and that the current alone without cocaine, could produce no cuta-

neous anæsthesia, but that there was an actual cataphoresis of the cocaine solution and consequent anæsthesia of considerable duration with the anode. I then proceeded to make therapeutic use of this method.

EXPERIMENT No. 12. *Successful Use of Cocaine; Cataphoresis in a Case of Supra-orbital Neuralgia.*—Dr. E. C. Seguin kindly placed at my disposal an obstinate and severe case of right supra-orbital neuralgia. L. E., female, aged 40 years. Duration of neuralgia, a year and a half. Everything tried unavailingly. Suffering every few minutes with the usual agonizing pains of the disease. There was slight analgesia over right half of the forehead and right side of the nose, but exquisite hyperæsthesia of the tactile sense in the same areas, so that a slight touch or breath of air was exceedingly painful. There was great tenderness on pressure. The two-centimetre square anode with a 10-per-cent. solution of cocaine was placed in the right supra-orbital region over a painful spot, and the eight-by-twelve-centimetre sponge and wire cathode in the right palm. Nine Grenet cells were used for three minutes, then raised to eleven cells for two minutes longer, which caused prickling, but no pain; and then raised to thirteen cells, which was too painful, and was reduced to twelve cells, and continued for five minutes. The whole application lasted ten minutes without break of current. There was no neuralgic pain during this time and the hyperæsthesia had disappeared. There was the expected anæsthesia. The patient was completely relieved from pain for from four to five hours.

EXPERIMENT No. 13.—A second similar application was made the next day in the same case, by Dr. Seguin, at his office, with equally gratifying results.

EXPERIMENT No. 14.—Same case and same electrodes as in No. 12. Seven Grenet cells; five milliampères current-strength; 10-per-cent. solution of cocaine; six minutes' application. Equal relief.

EXPERIMENT No. 15.—Same case and details. Eleven cells; 10-per-cent. solution of cocaine; six minutes. Equal relief.

EXPERIMENT No. 16.—Same case. Application by Dr. Seguin. Ten-per-cent. solution of cocaine; fifteen milliampères current-strength; twenty minutes' contact, moving slowly over different parts of right supra-orbital region. Very great relief for five hours.

EXPERIMENT No. 17.—Same case. Sixteen to twenty cells; 10-per-cent. solution of cocaine; five to seven milliampères current strength; nine minutes. Same relief. In this case aconitine pushed to its toxic effects did not relieve pain. The cataphoric application is still in use in this case, and always with the marked results mentioned. Latterly, several applications of the anode with a 20-per-cent. solution of cocaine have been still more distinctly beneficial. On one occasion she had eleven hours of perfect freedom from pain, the longest interval of relief in a year and a half. Whether any actual curative effect will be pro-

duced, it is now too early to determine. The patient herself is so convinced of the efficacy of this method that she will now try nothing else.

Experiment No. 18. *Successful Use of Cocaine Cataphoresis in Another Case of Chronic Supra-orbital Neuralgia.*—This second case was also placed at my disposition by Dr. Seguin. J. F., male, aged 60 years; extreme suffering from right supra-orbital neuralgia for twelve years. Internal administration of aconitine is gradually relieving him, but pains every few moments exceedingly severe. Same electrodes and application as in No. 12. Ten-per-cent. solution of cocaine. Five cells; six minutes. Anæsthesia slight. Pain relieved. Cannot endure so much current as No. 12.

Experiment No. 19.—Same case. Ten-per-cent. solution of cocaine; nine cells of Grenet battery; three milliampères and a half current-strength; six minutes and a quarter. Great relief and considerable anæsthesia.

Experiment No. 20.—Same case. Very little pain for past forty-eight hours since last application. Aconitine probably doing its work. Great tenderness on pressure over supra-orbital nerve. Cocaine as before. Eleven cells, seven minutes. Complete anæsthesia produced. No pain on pressure.

Experiment No. 21.—Same case and condition as in last. Cocaine as before. Fifteen cells; five milliampères; ten minutes. Same result.

Experiment No. 22.—Same as last. Fifteen to eighteen cells for eight minutes. Same result.

Experiment No. 23. *Successful Use of Cocaine Cataphoresis in Inferior Maxillary Neuralgia.*—Tried by Dr. J. A. Booth, and notes kindly furnished me by him. Inferior maxillary branch of left trigeminal. Neuralgia for three weeks. Cathode in right hand. Anode over left mental foramen. Ten-per-cent. solution of cocaine. Both electrodes five centimetres in diameter. Seventeen Leclanché cells; seven milliampères current-strength; five minutes and a half contact. Spoke very soon of relief caused. Slight anæsthesia produced.

Experiment No. 24. *Deep Analgesia with the Cataphoric Use of Aconitine.*—I now performed several experiments upon myself with the same apparatus as before, but substituting an alcoholic solution of aconitine (gr. iv to ℥j) for the cocaine on the anode. Result: In two or three minutes deep-seated analgesia, but tactile hyperæsthesia; a painful burning sensation, the area covered by anode whitened and elevated. The analgesia to pricking and the burning sensation continued for an hour. The pallor disappeared after a quarter of an hour, giving place to redness. There was no excoriation.

Experiment No. 25. *Relief of Dorsal Neuralgic Pains in Locomotor Ataxia by Aconitine Cataphoresis.*—S. B., male; a case of locomotor

ataxia suffering from intense neuralgic pains in the back at mid-dorsal region. Cathode on left side of abdomen. Anode one centimetre in diameter with aconitine, as in No. 24, to region of greatest pain. Fourteen Leclanché cells, five to six milliampères current-strength, four minutes' application. A white elevated disc, larger than the area of anode, was produced, which was completely analgesic and anæsthetic for an hour, but in which there was a burning sensation for an equal length of time. The neuralgic pains were relieved for eight or nine hours. This was tried again a few weeks later with 10 minims of tincture of aconite on the anode, with equal effect.

Experiment No. 26. *Relief in a Case of Double Trigeminal Neuralgia from Cataphoric Use of a Mixture of Cocaine and Aconitine.*—E. B., female, aged 30; excruciating double trigeminal neuralgia of a year's standing, upper two branches. Had tried blisters, electricity, and aconitine internally, and once had morphine habit. No day without pain. Twenty-eight chloride-of-silver cells. Water rheostat. Twenty-per-cent. solution of cocaine on anode one centimetre in diameter to right temple over painful spot for twelve minutes. Cathode six by ten centimetres in right palm. Complete anæsthesia and analgesia and relief in that side. Same for five minutes to left temple with like beneficial result. Then four minutes over main trunk of nerve in front of right ear, with a mixture of equal parts of 20-per-cent. solution of cocaine and the solution of aconitine (gr. iv to ℥j), causing deep anæsthesia to touch and pain. With this last there was slight burning sensation at first, but it subsided in a minute or two. Relief from pain experienced for several hours.

Experiment No. 27. *Cocaine and Aconitine Cataphoresis.*—I now thought it best to try some further experiments upon myself. A six-by-ten centimetre cathode was placed in the left palm, and the one-centimetre anode over the left first interosseous, as before. The anode was well saturated with a mixture of aconitine and cocaine, as in the last experiment. Twelve chloride-of-silver cells; five minutes' application. Result: Complete anæsthesia to touch, pain, and temperature over a space three times the area of the anode, without burning sensation as when aconitine was used alone. There was at first great pallor of skin beneath the anode, which gradually gave way to slight redness in a quarter of an hour. There was slight return of tactile sense in fifteen minutes, and in twenty minutes slight hyperæsthesia to touch, temperature, and pain.

Experiment No. 28. *Trial without Current.*—Same electrode, saturated with same solutions as in No. 27. Held it on the back of my left hand without the galvanic current for eight minutes, frequently rubbing in order to hasten absorption. There was no effect whatever, save redness produced by rubbing; no anæsthesia.

Experiment No. 29. *Very Mild Current for a Longer Period of Time Successful.*—As in some of the experiments here described

unpleasantly strong currents had been used, I tried upon myself the effect of a mild current for a longer period of application than usual. Same electrodes, points of contact, and solutions as in No. 27. Six chloride-of-silver cells; current imperceptible; ten minutes' duration. Marked anæsthesia to pain, touch, and temperature resulted as before.

EXPERIMENT NO. 30.—*Use of Chloroform without Current.*—Held a sponge, two centimetres in diameter, well saturated with Squibb's chloroform, against mid-dorsal surface of left hand, frequently rubbing for ten minutes. There was smarting, stinging pain during the whole application, with intense redness; a very slight superficial anæsthesia to touch, but none to pain of pricking. No current used. The trivial anæsthesia disappeared in two minutes, when the part became hyperæsthetic. The redness disappeared in an hour. There was no excoriation of epidermis.

EXPERIMENT NO. 31. *Cataphoric Use of Chloroform and Bad Effects.*—Same electrodes and position as in No. 27. Anode saturated with Squibb's chloroform; eighteen chloride-of-silver cells; six minutes' application. Complete anæsthesia to touch and pricking with needle in area of anode, lasting barely four minutes. Application more painful even than that of aconitine. There was no insulation by chloroform. The frequent use of the interrupter showed that a strong current was passing. There was a general redness at first. An hour later there was œdema and pallor, surrounded by an areola of redness. Twelve hours later there were swelling, congestion, redness, dermatitis, and vesication. A week elapsed before complete healing of the injury. There was sloughing of the epidermis and part of the cutis vera.

When I took up the subject of anodal diffusion, in the winter of 1888 and 1889, the bulk of information at my command was limited and uncertain.[1] There was so much controversy on every point, so much diversity of opinion, that even the existence of the cataphoretic power of electricity seemed to be as yet not scientifically proven. I therefore made some hundred experiments upon myself and patients, the most important of which have already been described above.

The results of these experiments were summed up as follows: The current alone does not produce anæsthesia at either pole, although the anode has a transitory soothing effect over painful foci. A watery solution of cocaine applied to the skin is not absorbed, does not produce anæsthesia, except, perhaps, after an indefinitely long period. The same is true of chloroform and of an alcoholic solution of aconitine. A

[1] The following are the titles of my original papers from which chiefly the materials for this chapter have been drawn: "Electric Cataphoresis as a Therapeutic Measure," N. Y. Medical Journal, April, 27, 1889; "Note on a New System of Exact Dosage in the Cataphoretic Use of Drugs," N. Y. Medical Journal, November 15, 1890; "Farther Studies of the Therapeutics of Anodal Diffusion," N. Y. Medical Record, January 31, 1891; "The Introduction of Drugs into the Human Body by Electricity," Phila. Times and Register, March 21, 1891.

watery solution of cocaine is diffused through the skin and subcutaneous tissues by the anode, but not by the cathode. This is true of chloroform, aconitine, strychnine, potassium iodide, corrosive sublimate, tincture of iodine, and other medicaments. The anæsthesia produced by a 10- to 20-per-cent. solution of cocaine on the anode is sufficient for small operations and affords distinct relief for from four to eleven hours in cases of severe neuralgias in superficial nerves, and without constitutional effects. The Adamkiewicz electrode is absolutely worthless, since it is so stupidly constructed that the current does not pass through the fluid contained within it, but through its circular metallic rim. Chloroform, recommended by Adamkiewicz, and by Lumbroso and Matteini, should only be used for cataphoretic purposes when, in addition to producing a local anæsthesia, it is desired to counter-irritate, for it causes a disagreeable dermatitis of a week's duration, as I have had reason to learn by experiment upon myself. It does induce a deep analgesia beneath the anode, but it also vesicates.

Up to February, 1889, I had employed anodal diffusion of solutions of cocaine and aconitine, separately or mingled, in two severe cases of chronic supra-orbital neuralgia, selected for me as crucial tests by Dr. Seguin; in one case of double trigeminal neuralgia; in one case of inferior maxillary neuralgia; in one case of locomotor ataxia for the relief of dorsal neuralgic pains. The success of the measure in all of these cases was undisputed. It gave hours of relief from excruciating pain, and without constitutional effects of any kind. Nothing was claimed for it as a curative procedure, but it certainly proved to be a more than efficient substitute in these cases for morphine, which, as we too well know, is so prone to exact for its hours of solace life-times of wreck and ruin. After the publication of my earlier paper, with the results of experiment and of therapeutic application, other articles began to appear which showed a growing recognition of the value of the method.

Dr. Cagney,[1] of London, reported his experience in the use of cataphoresis before the Harveian Society, November 7, 1889. He employed iodine and a saturated solution of potassium iodide with the anode for labyrinthine deafness, lead palsy, small tumors of the skin and mucous membranes; for syphilitic and other throat affections; for chronic pharyngitis; for nodes and gummata, tubercular ulcers, mucous patches, and papular syphilides; for indolent ulcers, lupus, acute and strumous glands. In the discussion upon Dr. Cagney's paper, Mr. Juler stated that he had found the method useful in tobacco amblyopia.

In the same month Drs. Gärtner and Ehrmann[2] made a communication to the Imperial-Royal Society of Physicians of Vienna, in reference to the cataphoretic use of corrosive sublimate. Dr. Gärtner's electric bath-tub was employed, from four to six grammes of mercuric

[1] British Medical Journal, November 16, 1889.
[2] Wiener med. Blätter, November 28, 1889.

bichloride being dissolved in the water of the bath. A current-strength of one hundred milliampères was passed through the person experimented upon for fifteen or twenty minutes, and subsequently mercury was found in the urine in as large a quantity as 1.3 milligrammes. There were traces of the metal in the urine for from four to six days after the bath.

Some time ago Boccolari and Manzieri[1] announced their intention to study the effects of electric cataphoresis in connection with mineral baths, but I have been able to find no published results of their studies in this direction. They have published, however, their use of anodal diffusion of drugs in parasitic affections of hair-roots.

Woodbury[2] described, in May, 1890, his successful employment of the anode with a solution of iodide of lithium in a case with a syphilitic cutaneous neoplasm. Shoemaker[3] has also written upon the uses of cataphoresis in certain skin diseases. Dr. A. Barth[4] describes cocaine cataphoresis as employed by him in a number of operations upon the tympanum and external auditory meatus, finding a 10-per-cent. solution on cotton connected with the anode very successful.

At the International Congress held at Berlin, in August, 1890, Dr. Bayles, of Orange, N. J., read a communication from Mr. Edison, the inventor, upon the medical employment of cataphoresis. I am indebted to my friend, Mr. A. E. Kennelly, chief electrician of the Edison laboratory, for the following brief synopsis of Mr. Edison's experiments :—

"The first trials were purely physical. With a current of twenty milliampères, lithium chloride was forced through a septum of animal membrane by electrical endosmosis. The second series of trials was upon the person of a healthy young laborer, who dipped one hand in a solution of common salt, and the other in a 5-per-cent. solution of lithium chloride in water, for two hours daily for ten days. His urine, examined before the test, showed no more than mere traces of lithium. His urine, collected during that period, exhibited distinct presence of lithium. Five milliampères. The third trial was upon the person of an old man suffering from acute and chronic uric-acid concretions. He was in an advanced stage of the ailment, and most of his joints were affected; the joints between the phalanges were almost obliterated. He immersed one hand in lithium-chloride solution, the other in common-salt solution, while a current from the 120-volt electric-light circuit was employed through resistance to pass through his body. Measurements of the hand in the lithium-chloride solution showed, after some twenty-five hours of total application, a distinct reduction of bulk. There was also considerable relief from pain, and the general condition of the patient was

[1] Internat. klin. Rundschau, September 2, 1888.
[2] Philadelphia Med. News, June 21, 1890.
[3] Sajous's Annual, 1890.
[4] New York Archives of Otology, April–July, 1890, New York, pp. 100, 101.

ameliorated. The current-strength in his case was 20 milliampères (four times more than the previous healthy subject could stand with convenience)."

The earlier criticisms of medical men, that there was no such thing as the anodal diffusion of drugs, must, in the face of such accumulating evidence, be entirely silenced. It is only a few years ago since, in the discussion of my first paper, some who took part manifested entire incredulity. The far more vital criticism, however, that accuracy of dosage was impossible by this method of medication, was not answered until after further experiment and some thought upon the subject. I published in the *New York Medical Journal*, November 15, 1890, a "Note on a New System of Exact Dosage in the Cataphoretic Use of Drugs." The great drawback, until that time, had been the difficulty of accurately regulating the amount of drug introduced. For this purpose rather complicated electrodes had up to that time been required, and even these had been unsatisfactory. The hollow electrode of Munk with clay bottom, of Adamkiewicz with carbon bottom, and of myself with a membranous bottom, each had failed to determine properly the quantity of the medicament employed. But this is now no longer a valid argument against anodal diffusion, since, by the means I have of late employed, exact dosage is simplicity itself. It is only essential to possess a flat metal electrode, preferably but not necessarily of platinum (platinum is now almost as costly as gold) or tin. A nickel-plated surface will answer. Walling uses a carbon surface, which is probably the best form of all for a cataphoric electrode, although its porosity is a disadvantage; but this may be overcome by impregnating with hot paraffin. This may be made of any size, round or square, convex or concave. A piece of tissue- or filtering- paper or linen is cut to fit over the metal surface. Upon it is placed, drop by drop, the solution of any drug to be used, and the electrode is then applied to the skin. There is then a thin capillary layer of the medicament in the paper disc, between the electrode and the skin, and the quantity of the drug is known. The electrode made for me by Messrs. Waite & Bartlett, of this city, is round, flat, two or three centimetres in diameter, and is provided with a narrow soft-rubber rim at its edge, which, by its close approximation to the skin, prevents any loss of the solution by evaporation. In order to have drugs ready for use at any time, discs of paper to fit the electrode may be charged with aqueous or alcoholic solutions, and then allowed to dry, a drop or two of menstruum being added when they are to be used.

The current is allowed to flow if desired until the medicated disc becomes perfectly dry. In this way we may drive in one or more drops of chloroform, methyl chloride, ether, 10- to 20-per-cent. solutions of cocaine, a 1-per-cent. solution of helleborine, solutions of iodide of potassium, corrosive sublimate, aconitine,—in fact, any drug we wish to employ

in this manner, and at the same time we know exactly how much we are using. To further simplify the method, I have had medicated cataphoretic discs prepared by a pharmacist for use at any time, for the paper discs may be charged with any amount of a watery solution, and, the water being allowed to evaporate, they may be kept on hand indefinitely. It is only necessary to add two or three drops of water to the disc in administering the drug by electricity.

Mr. Otto Boeddiker, the apothecary, of 954 Sixth Avenue, New York, has made for me, and is prepared to supply any one with, the following cataphoretic discs: Discs of menthol, 2 grains; of helleborine, $\frac{1}{25}$ grain; of strychnine nitrate, $\frac{1}{32}$ grain; of iodol, 2 grains; of corrosive sublimate, $\frac{1}{8}$ grain; of cocaine hydrochlorate, $\frac{2}{5}$ grain; of aconitine, $\frac{1}{64}$ grain; of potassium iodide, 4 grains; of mercury succinimide, $\frac{1}{4}$ grain; of lithium chloride, 4 grains.

Dr. Morton has improved upon my paper discs by employing a soluble gelatinous disc impregnated with the drug.[1] It is sometimes useful to prepare the skin a little before treatment, by rubbing with ether, to dissolve out the oil-globules. The anode being applied with the drug, the cathode may be placed anywhere upon the surface of the body, and a current of any endurable strength turned on. The stronger the current, the speedier the effect.

Besides the use of these simple electrodes, it is often desirable to make more extensive applications over wider areas. If, for instance, it were wished to diffuse a solution of lithium about a large joint like the knee, a sufficiently large strip of zinc is covered with sponge or cloth saturated with the solution, tied around the extremity, to be then connected with the anodal rheophore. For diffusion through the whole body a bath-tub is used, one either constructed for the purpose or any ordinary bath-tub. The common bath-tub of our houses is readily converted into an anode by placing a large sheet of zinc on the bottom, and connecting it with an insulated copper wire. The sheet of zinc is then covered over with a board to prevent its contact with the body. When the patient is immersed in the bath, he merely keeps one arm out to grasp the cathode, and the circuit is made.

These are, in brief, the means by which drugs are introduced into the body, and it is clear that any soluble agent may be employed in some one of the ways described. In applying electricity for cataphoretic purposes, it does not matter what kind of cell is employed, but a rheostat and galvanometer are useful if not actually necessary. As regards the current-strength to be employed, one must be guided by the patient's feelings. Anywhere from 5 to 20 milliampères may be used for from five to fifteen minutes. The stronger the current, the shorter the duration of the *séance*. If one has no galvanometer, he may use ten to

[1] N. Y. Medical Journal, 1891.

thirty or more cells of any battery,—Grenet, Leclanché, or chloride of silver.

The *therapeutic indications* for the application of this method of treatment may be thus summarized:—

I was led myself into making a study of electric cataphoresis by my own work in a neurological line, and my first experiments were conducted with a view to relieving pain. I received the suggestion after vainly endeavoring to combat severe supra-orbital neuralgias in several patients. All known appliances and agents of the healing art had been ineffectual,—blistering, electricity, aconitine, and the progressive series of narcotics and anodynes, which generally terminate with the morphine habit. One of the patients had suffered from morphine inebriety for a year, but had recovered from that with her supra-orbital anguish unassuaged, as reported above. I found that 10- to 20-per cent. solutions of cocaine on the anode gave absolute relief in these cases for from four to ten or eleven hours, and without constitutional effects of any kind. A deep analgesia was produced in the area covered by the anode. No doubt constitutional effects would ultimately result by indefinite continuance of the application.

Since that time I have made it a point always to use the cocaine solution in any sort of superficial pain in which I think the anode to be of advantage. The method does not mitigate neuralgic pains which owe their origin to lesions far back of the point to which the electrode is applied, as in disease of the Gasserian ganglion, or the idiopathic neuralgias of central origin; and it is here that cocaine cataphoresis has an actual diagnostic significance.

In the discussion which followed the reading of my first paper upon this subject, Dr. Starr called attention to the possible usefulness of cocaine cataphoresis in diagnosis. Thus, if a pain were complained of, for instance, in some part of the trigeminus, it should disappear under this treatment. If it did not, the lesion could be localized farther back, or it might lead to the conclusion that it was hysterical pain. I had myself an interesting example of its usefulness for this purpose some time ago. I was called in consultation to see a lady who had been suffering for months with a rather superficial but excruciating pain in the knee, following slight trauma. The knee was swollen from blistering, the limb was rigid, the patient sleepless from pain, and anxious to have the leg amputated. The spot upon which I placed the anode with cocaine was so hyperæsthetic that the slightest touch made her wince with pain. Her eyes being closed, I stuck a pin in the part after a few minutes, which she did not notice. When she opened her eyes, the electrode having been removed, I touched the anæsthetic part with my finger, and she winced with pain, the same as before. Although the limb was, I believe, subsequently amputated, my diagnosis of a hysterical knee-joint was amply corroborated by microscopical examination. It

had, also, some sort of corroboration in a case of intense supra-orbital neuralgia which I saw on one occasion with Dr. Starr. A 20-per-cent. solution of cocaine used with a strong current for a considerable period of time did not diminish the paroxysms of pain in the least. A few days afterward neurectomy was performed, and this also had no effect upon the neuralgia, which showed the central character of the lesion.

To Produce Local Anæsthesia for Neuralgias, Superficial Pains, and Cutaneous Operations.—With an additional experience of several years in the frequent treatment of neuralgias of superficial nerves with 10- to 20-per-cent. solution of cocaine on the anode, I can only reiterate my conviction that it is the best means we have for relief of such conditions. Cocaine employed in this way does not *cure* neuralgias of peripheral origin. All that is claimed for it is that it gives relief without producing constitutional effects, and is, therefore, superior to any narcotic given internally, and to any other local application. I have had no experience of the method in surgery, but I quote the following from a letter received from Dr. R. H. M. Dawbarn, June 10, 1889, which will merely serve as an instance of the successful employment of voltaic narcotism in a small operation:—

"I have recently, since reading your article, tried this method upon a child's hand requiring suture of a severed tendon. The injury was an old one, and there was no wound before I made my incision. The anæsthesia from 10-per-cent. cocaine upon the anode, continued with my chloride-of-silver battery (twelve cells) for ten minutes, was very satisfactory."

I have experimented with other local anæsthetics. Aconitine produces a deep analgesia, but it is accompanied with severe smarting around the edges of the anæsthetized area. A combination of cocaine with the aconitine prevents this hyperæsthesia. I was led by a note on helleborine [1] in a medical journal to make use of this alkaloid as a local anæsthetic. Three or four drops of a 1-per-cent. solution of helleborine on the anode have brought about much more gratifying results than cocaine, a deeper and more lasting anæsthesia, and I have never noted constitutional effects. The latter need not be feared, now that dosage has become accurate. At the same time I should advise caution in the employment of so powerful an alkaloid.

Both ouabain and strophanthin[2] (Arnaud's, not Merck's) are strong local anæsthetics, and may be used with the anode in doses of $\frac{1}{250}$ grain or more. One or two drops of chloroform on a tissue-paper disc, placed upon the anode, will bring about a deep analgesia in a very short time, but will be followed later by vesication. When it is desirable to first anæsthetize and then counter-irritate, chloroform cata-

[1] Venturini and Gasparini, British Medical Journal, August 4, 1888.
[2] Fortschritte der Medicin, February 1, 1890.

phoresis may be advisable, and will prove useful in some neuralgias. A mild solution of carbolic acid may also be employed as a local anæsthetic and analgesic.

For the Relief of Local Muscular Spasm in Superficial Muscles.—While my experience with the method has been chiefly in neuralgias of superficial nerves, I have not failed to give it a trial in other conditions where it seemed to be expedient. I have used cocaine and helleborine with the anode in two cases of tic convulsif, placing the electrode over the trunk of the facial or one of its branches. Whatever may be the explanation of its effect, these cases certainly showed very great improvement and a remarkable diminution of the spasm after each application, such as was not obtained from the employment of the electric current alone.

In a case of blepharospasm, cocaine cataphoresis practiced near the outer angle of the eye produced a very marked change in the extent and frequency of the movement. I have no doubt, however, that the results would be better still if we had some drug to use with the anode which would act upon motor nerves in the same way as the local anæsthetics act upon sensory nerves,—if, in other words, we had some trustworthy local paralytic. Atropine and curarine do not seem to answer the purpose.

Effects of Cataphoresis upon Nutrition in Ordinary Applications of the Galvanic Current.—There can be no doubt that the effects of the galvanic current upon nutrition are in part due to the cataphoretic transfer of molecules of protoplasm and liquid from one cell to another, or from a cell to a capillary vessel in the path of the anodal stream; and since the diffusion takes place more readily and more quickly in direct proportion to the current-strength, it behooves us to employ as many milliampères as feasible in our galvanization of the atrophied and paralyzed extremities of poliomyelitis, chronic neuritis, and peripheral-nerve trauma.

Moreover, there would seem to be a possible advantage in the use of nutritive emollients in conjunction with the labile application of the anode to the atrophied member, just as they have been combined from time immemorial in the exercise of the aliptic art (massage).[1]

For Electro-Cataphoretic Baths for General Purposes.—There would seem to be considerable usefulness in the method as applied to mineral baths. Although Gärtner has been at great pains to invent a particular kind of bath-tub with two compartments for electrical purposes, it is not essential to have any such arrangement. By making an ordinary bath the anode, the hands may close the circuit by grasping a cathode suspended just above the bath. Thus almost the whole surface of the body may be subjected to the anodal diffusion of the therapeutic agent dissolved in the bath.

[1] "The Aliptic Art," by Frederick Peterson, M.D., Phila. Medical News, August 11, 1883.

Outside of tonic, stimulating, and alterative, such as are found in health resorts, cataphoretic baths of iodide of potash might prove useful in cases of lead poisoning, etc.

For Topical Medication in Various Local Lesions, such as Tumors, Rheumatic, Gouty, and other Swellings, Various Skin Diseases, Syphilides, etc.—For such cutaneous disorders as are commonly treated by painting with iodine, the use of some of the iodine preparations, such as potassium, sodium, or lithium iodide, iodol, or diluted tincture of iodine upon the anode is indicated.

For rheumatic and gouty swellings, solutions of the chloride, benzoate, or citrate of lithium (all very soluble salts) should be employed with the anode. Dr. Imbert de la Touche has written a very interesting pamphlet lately, entitled "Traitement de la Goutte et du Rheumatisme par l'Électricité," read before the French Association for the Advancement of Science, in September, 1891, in which he describes the successful treatment of such cases by the cataphoretic application of iodide of lithium, and of a solution of bryony (bryone). Among mercurial remedies the imido-succinate and bichloride of mercury are well adapted for cataphoretic purposes. The rhinologist and laryngologist will find the method particularly adapted to the treatment of many difficulties of the upper air-passages, which may require the application of anæsthetics, astringents, or antiseptics.

As a last word, let me say that, while the constant current has proved so very useful to the medical profession for diagnosis, for stimulating nerve and muscle, for electrical endoscopy, and for cauterization, we must not neglect its cataphoretic property, by which remedial agents are diffused through the tissues and fluids of the body to improve nutrition, to produce anæsthesia, to relieve pain, to destroy germs, to modify morbid processes, and to make soluble chemical combinations with deleterious substances which quite frequently collect in the organism.

In view of all the facts which I have adduced in this chapter, there can be no doubt that the anodal diffusion of drugs is destined to far wider application than it has as yet enjoyed, and that the general practitioner and the specialist alike will find the procedure increasingly useful as a practical therapeutic measure. As I have elsewhere[1] written, it opens a way not otherwise attainable for influencing tissue metabolism and for changing morbid nutritive processes, by sending the drugs into direct and immediate contact with diseased parts, through a force which in itself must greatly enhance their active medicinal properties.

In gynæcology cataphoresis has found many friends, and is giving cheering results. In the ordinary inflammatory conditions the general practitioner will find in it a safe and sure remedy. Every day adds to the literature of the subject, which is valuable, because original.

[1] New York Medical Journal, December 28, 1889.

LITERATURE.

Besides those already referred to in the text, there are the following articles which may be consulted: Lewandowski: Article "Kataphorese," in the Therapeut. Lexikon of Dr. A. Bum. Morton: "Note on a New Method of Cataphoresis (Anæmic Cataphoresis)," N. Y. Med. Journ., p. 473, 1891. Ehrmann: Wiener med. Wochenschr., February 1, 1891. Harries: Med. Press and Circular, December 11, 1889. W. H. Walling: Medical World (Phila.), November, 1891. B. W. Richardson: Asclepiad, 1891. "Proceedings of Am. Electro-therapeutic Association," 1892, published in the Journal of Am. Med. Asso., and containing discussion on cataphoresis by Drs. Peterson, Morton, Goelet, and others, and by Messrs. Kennelly and Houston, electricians.

INTESTINAL OCCLUSION TREATED BY ELECTRICITY.

By DR. LARAT,

PARIS.

Within the last fifteen years the treatment of intestinal occlusion has been discussed in most of the congresses of surgery, and, judging from the majority of opinions expressed, medicine has been put aside and surgical operations have been more than ever used for the treatment of this dreaded disease. Thus, in 1887, when the treatment of intestinal occlusion was discussed at the Congress in Washington, medical means were considered inefficient, and an immediate surgical operation was thought necessary. The word electricity was scarcely mentioned. In April, 1889, at the Congress in Wiesbaden (Germany), Curshmann, from Leipzig, while treating of therapeutics with the authority he enjoys from his important works on intestinal occlusion, passed in review all the medical means which he thought should be used before having recourse to surgery. He only forgot one,—Electricity! At the Surgical Society in Paris, where intestinal occlusion has often been brought up, if a few of the individual members, such as MM. Monod, Terrillon, Labbé, Routier, and others, recommended using electrization before any surgical intervention, others considered medical treatment as fatal, on account of its delaying the operation which alone could save the patient.

Thus, the treatment by electricity of intestinal occlusion has not yet come into ordinary practice; and, if some doctors have thought of it, very few have employed it, and many ignore it completely. The object of this chapter is to prove that this neglect is unjust and much to be regretted, and that many cases of intestinal occlusion could be cured by judiciously applying electricity, or, at least, certain forms of this disease. In fact, it is only since the beautiful works of Duchenne, of Boulogne, on "localized electricity" that attention has been drawn to the advantage of this means for the treatment of obstinate constipation and intestinal obstructions, and, as this clever experimentalist used induced currents almost entirely for his physiological and pathological studies, doctors, as a rule, have had recourse to these same currents. This can be verified by most of the remarks on occlusions published at that period and in the following years.

However, already, in 1876, Leroy d'Etiolles observed that smooth muscles were not affected by faradic excitations, and that, on the contrary, these are most powerful in causing the contraction of striated

muscles. Later (1882), Boudet, of Paris, insisted on this distinction, and he proved that only slow excitations of continuous currents, leaving a space between each, can have any direct influence on intestinal contraction, and, consequently, for the treatment of occlusions galvanization should be preferable to faradization.

Between these two periods, characterized, one by the works of Duchenne, of Boulogne, the other by the researches of Boudet, of Paris, a whole series of memoirs on this subject has appeared in France and in other countries, some of which are: "Therapeutic Considerations on Intestinal Obstruction or Strangulation" (Tripier); "Intestinal Obstruction Cured by Faradization" (Keyhel); "Ileus Cured by Faradic Electricity" (Macario); "Intestinal Occlusion from Intussusception" (Bogdam); "Good Effects of Electricity for Strangulation and Intestinal Obstruction" (Duteuil); "Intestinal Occlusion Cured by Electricity" (Dal Monte); "Intestinal Occlusion Treated by Faradic Electricity" (Fleuriot); "Cure of a Case of Intestinal Obstruction by the Application of Induced Currents" (Mario Gommi); "Intestinal Occlusion After Traumatism" (Chouet); "Practical Considerations on the Treatment of Intestinal Intussusception from Three Cases Cured by Electricity" (Bucquoy); "Intestinal Occlusion Cured by Electricity" (Doyen); "Inaugural Thesis" (Bollouhey); "A Case of Intussusception and another of Accumulation of Fæces Cured by Faradic Electricity" (Caubet); "On Intestinal Occlusion" (Trappenard); "Intestinal Obstruction from a Bilious Calculus—Expulsion of the Calculus by Electricity" (Magnin); "Notes on a Case of Intestinal Internal Strangulation" (Bérenger-Féraud); "Cure of a Case of Occlusion by Electricity" (Henderneich); "Intestinal Occlusion Cured by Faradic Electricity" (Daviller); "Combined Inversion and Faradization for the Treatment of Internal Strangulation" (Follet); "Intestinal Obstruction—Probable Paralysis of the Intestine" (Christison); "Intestinal Occlusion from Volvulus" (Kaczorowski); "Intestinal Obstruction from a 'Stercorate' Tumor" (Wharton); "Ileus with Serious Symptoms" (Mac-Cormac); "Intestinal Intussusception" (Moutier); "Two Cases of Occlusion, Peritoneal 'Stercorate' Frenum" (Boudet, of Paris); "Remarks on Intestinal Obstruction in the Ascending Colon" (Cornil); "Treatment of Intestinal Occlusion by Electricity" (Bloch); "Notes on the Use of Continuous Currents for the Treatment of Intestinal Occlusion" (Monod); "On the Treatment of Intestinal Occlusion by Electricity" (Report to the Academy of Medicine by Herard).

From this nomenclature it is clear that, like Duchenne, of Boulogne, operators used sometimes faradic electricity, and sometimes, like Leroy d'Etiolles, galvanic currents. Let us see if, actually, we can form an opinion as to the value of these two methods, and for which cases they should be applied. Many physiological experiences have proved that

smooth muscles are difficult to excite with faradic currents. The reason is entirely a physical one, as the faradic current consists of shocks that last but a very short time. This, however, is sufficient to excite a striated muscle, the contraction of which is lively, quick, and distinct; but not powerful enough to move a smooth fibre, whose contraction can be characterized by a graphic line forming an elongated wave. However, if, for an experiment, the faradic current should be applied on the intestine of a healthy animal, very active peristaltic movements would be perceived in a few seconds; but should the excitability of the intestine be artificially diminished,—and the simplest way to obtain this is to distend it by insufflation of air, in order to produce slight palsy by mechanical distension,—the faradic current would remain inactive; at least, it would be within the limit of medical doses; while, on the contrary, the continuous current, under these circumstances, is quite capable of causing intestinal contraction. And if, instead of allowing the current to run in the same direction, a few inversions should be made, the intestine will be found to contract as energetically as if it were not distended.

Theoretically, as in a case of intestinal occlusion, the intestine is always more or less palsied, either by distension, by intestinal irritants, by the shock of the operation, or by the exhaustion of the contractibility from long and violent efforts. Thus, it seems better to have recourse to continuous currents. However, for a long time there has been one obstacle to this kind of electrization. This obstacle is caused by the chemical action or electrolytic of the currents of the battery; for there might possibly be a formation of eschars not only on a level with the exciter, but even on a certain zone around the intestinal electrode.

The fact was to solve the following problem: How to give the intestines a galvanic current of sufficient intensity which should last long enough to accumulate a considerable degree of energy, and at the same time avoid the local chemical action on a level with the exciters? This question was happily decided by M. Boudet, of Paris, who found that the injection called electric had the advantage of distributing electricity on a large surface of the intestine. Before this a metallic electrode was used as an intestinal probe when galvanic electricity was employed, and either the current being of too great ampèrage caused the production of eschars in the mucus more or less deep, or being less intense its action on the abdominal nervous system was not sufficient; consequently, on one side failure and on the other danger. The fashion of faradic electricity during many a year must be attributed to these causes. In these days, I think, this last form should be used only for rare cases, or when the necessary instruments for applying the galvanic current are not on hand.

I shall now proceed to describe the operative manual of an electric injection. The instrument is composed of: 1. A continuous electric battery capable of giving a very large ampèrage with a resistance of

one thousand ohms. The type is of no consequence, as long as this aim is reached. 2. A large metallic plate, covered with a layer of agaric and of camel's skin, nine centimetres by twelve, or even two of these plates joined together; in fact, it is most necessary to extend the surface of application as much as possible, in order to diminish the density of the current. 3. A gum probe supplied with a metallic hollow mandrin, to which is adapted an India-rubber tube, and on which can be screwed the peg of the conducting-wire, thus uniting the mandrin to the galvanic battery. The gum probe has a hole placed on the side at about two centimetres from the end, or an opening situated quite at the extremity of the probe. In this case the metallic mandrin should stop two centimetres farther back. 4. Lastly, it has an ordinary irrigator filled with tepid water, saturated with common salt. The plates, well imbibed with tepid water, must be placed on the abdomen of the patient and connected to the negative pole of the battery. The probe, supplied with its mandrin, is introduced in the rectum as deep as possible. In some cases the probe penetrates easily in all its length, but in most cases the operator is stopped in the rectal ampulla. Sometimes the upper end of the intestine can be found by a little groping and patience, but generally one is obliged simply to place the beak of the probe in the ampulla, which has become insurmountable, either from the effects of a curvature of the intestine or a stricture in its coating, occasioned by the accumulation of gas above, or perhaps owing to the presence of an organic or "stercorate" tumor. The reason for penetrating the beak of the probe as deep as possible is in order to introduce the mass of salt water constituting the injection on a part of the intestines where the reflexes, which produce defecation, are not as active.

When the probe is introduced, as I have just described, the India-rubber tube in connection with it is adapted to the faucet of the irrigator, and a wire conductor then connects the mandrin to the positive pole of the battery. When things are thus arranged, the cock of the irrigator is a little opened and half its contents are allowed to pass *slowly* into the intestine. The salt water flows over it, receives the electricity, and fills the intestine, while it carries the electricity on all parts where it comes in contact with the mucus. In fact, this acts like a very extensive liquid exciter, and, as the surface action of the current is very large, remarkable intensities can be employed without producing pain. The amount of electricity to be given to the intestine depends, however, on the state of the patient and on the cause of the occlusion. The length of time of the application for each sitting can vary between five and twenty minutes.

In many cases, such as pseudo-strangulation and obstructions of "stercorate" matters, it is sufficient to use a continuous current without shocks; but where there is an obstacle to overcome it is necessary to add stronger excitation. In this case, after causing the continuous current to pass during five or six minutes, it should be reversed by first

bringing the needle of the galvanometer back to zero, then leading the handle of the collector to the point it held at first. At this time an intestinal contraction is almost always produced, as well as a great desire of defecation. The patient should resist this desire as much as possible, but soon will no longer be able to control it. This is the moment to stop the current; the probe must then be taken out, and the patient make every effort to get rid of the fæcal matters. Then one of these three things will follow: either an abundant evacuation will take place, a regular clearing out, and in this case a rare one (after a first sitting electricity has been a success, and a few injections or purgatives will suffice to clear the intestine); else, only some liquid matter mixed with gas will be ejected; or, lastly, the injection will pass hardly colored, with or without gas. In the last two cases another application must be made, though not immediately, as the patient is tired out by the efforts he has just made; but it should take place seven or eight hours afterward. In fact, three applications can be made within twenty-four hours.

This is the technique of intestinal galvanization by means of an electric injection. Let us now see what the therapeutic results are. Boudet, of Paris, in statistics taken from fifty cases, counts the successful operations at 70 per cent. As far as I am concerned, I have now applied the electric injection two hundred and thirty times, and on these two hundred and thirty cases I have obtained the clearing of the intestine a hundred and one times. Thus, my successes are less, in proportion, than those given by Boudet, of Paris. However, they still remain satisfactory. All my cases have been seen by my colleagues, who called me in to assist their patients, and at least half of them are doctors in the hospitals. Thus, my statistics have been well tried, and it would be easy for me to call in the testimony of my colleagues and masters.

It seems to me useless to insist on anything more to prove the therapeutic value of electricity for intestinal occlusion. We have now to show the indications and contra-indications of the method, the time when it should be applied, and the symptoms of the different cases. As for indications, the theoretical question is very easily solved. There is evidently no chance of removing an ileus by any kind of intestinal excitation; the same can be said of a very much tightened sphincter or a twist of the intestine held by adherences. In fact, all insurmountable mechanical obstacles, either outside of the intestine or contained within its cavity, must be treated with the knife, and electricity should be used every time the obstacle can be overcome by a very strong contraction of the intestine, as in cases of "stercorate" obstruction, intestinal palsy, "entéraptose," stricture from a tumor if the astriction is not absolute, or a strange body being in the intestinal cavity.

Considered in this way, the question seems very simple. However, if facts and not theories are taken into consideration, it is a most complex and difficult one. In an immense majority of cases, what does the

doctor declare when called in to see a patient suffering from occlusion? He finds a flatulent belly, sensitive to the touch, which makes any direct examination almost impossible; the rectal touch rarely gives any useful indication, and to determine the cause of the occlusion one is obliged to trust general signs. Now, hypotheses can be formed from generalities coming near to the truth, but I may say they never allow one to form a decided opinion or make a good diagnosis. If one has ever so little experience in these things, one must agree that it is better to give no opinion, and that the most logical deductions relying only on generalities cannot be used as a serious basis for a precise diagnosis. Most authors who have written about the treatment of intestinal occlusion do not seem to have noticed these difficulties. To listen to them, it would be believed that it is sufficient to follow a rule. This is a serious matter, as it is a question of laparotomy or not. It is sufficient, they say, to make a diagnosis to know if one should immediately have recourse to surgery or not. They do not add that most of the time this diagnosis is almost impossible.

Now we return to facts. A patient presents himself to us suffering from intestinal occlusion, cause unknown. What should be done? Many surgeons say: The belly must be cut open without delay, because, if the operation takes place at once, it is the more likely to succeed. This is true; but the operation is very serious,—one of the most serious in surgery. If either laparotomy or a false anus is done, in the first case the mortality is enormous, in the second case a disgusting infirmity remains as a result of the operation; and many patients, being foretold of this, prefer death. The progress of "antisepsis" does not seem to have made much difference in the percentage of mortality. It is also impossible to avoid infection: not only is it to be feared outwardly, but inwardly. The intestine being distended, and full of old and fermented fæcal matter intensely poisonous, allows these poisonous products to pass through its coat, and often, notwithstanding the ability of the operator and the antiseptic care, the peritoneum becomes infected. From what Peyrot says, the mortality is 64 per cent. Schramm, in a recent statistic, places the mortality at 58 per cent. Thus, all operations for intestinal occlusion remain extremely serious; and on account of this it seems only natural to attempt the medical means we have at hand, and which, far from "causing the delay of the only intervention truly indicated," as Mr. Chaput, with great exaggeration, pretends, have saved quite as many patients as surgical operations.

This, then, is what I consider the best way to act: For a case of intestinal occlusion, having tried a purgative without any result, not to insist any longer, but immediately apply an electric injection. In twenty-four hours this will be recognized, successful or not. In case of failure, propose a surgical operation to the patient. If doctors followed this advice, there would no longer be cases where the electrician or the sur-

geon is called in too late, with no chance of success for either. No time would be lost, and the patient would be in excellent condition for an operation if the bistoury is necessary.

We will now pass on to contra-indications. Peritonitis has been called a contra-indication to electric treatment. I think the two following notes will sufficiently do away with this objection :—

Note I.—Thursday, February 28, 1884, Laemec came to the hospital and was placed under the care of M. Ball. He was a young typographer, suffering from all the symptoms of intestinal occlusion, caused by indigestion from drinking so-called old wine; this had given him violent colics, followed by vomiting and retention of gas and motions. On his entrance at the hospital his facies was slightly contracted and his temperature at 37 degrees. An examination of the epigastric region revealed a rather voluminous tumor, starting from the right side and spreading to the region of the left hypochondria. By percussion this mass was found to offer a decided dullness of sound. A distinct depression was seen on a level with the left flank, forming a contrast with the tumor confined within. They diagnosed an intestinal intussusception, and a rectal injection of siphon of Seltzer water and electricity was prescribed. Faradization, being applied according to the ordinary process, the negative pole placed in the rectum and the positive pole in the abdominal region, was very painful and gave no relief. M. Micaise, called in Saturday morning by M. Ball, did not consider a surgical operation necessary as yet; besides, he noticed some slight beginning of inflammation in the peritoneum (the belly completely swollen and pains all over). He advised injections of morphine and ice on the belly; and if by the next day the course of matters were not re-established, M. Boudet, of Paris, was to come and administer an electric injection before deciding on an operation. Saturday night his temperature had risen to 38° C., his pulse beat a hundred and four times a minute, and the symptoms of peritonitis were more decided. Sunday morning, temperature 38.8° C.; pulse, 108. M. Boudet, of Paris, came and at once applied the electric injection. The result was immediate. As soon as the probe was removed, the assistants could hear the noise of gas; this was a sign that the intestinal passage was re-established, —at least, for gas. Ten minutes afterward a rather hard motion took place, and a few minutes later diarrhœal evacuations. In the evening his temperature rose to 40° C. Ice was placed on the belly, and an injection of morphine was given. Monday, 39° C. Tuesday, the abdomen was less strained and not so painful; temperature, 38° C. The following days he was progressively better. The 8th of March he was convalescent. The 14th of March the patient left the hospital completely cured.

Note II.—The following note (procured by M. Poupon, house-surgeon) has no less significance. A distinguished house-surgeon, M. A., was subject to habitual constipation, which he constantly neglected. The 15th of November, 1888, he suddenly felt a sharp pain in the abdo-

men; he went to bed and sent for his master, Dr. Ferrand. The latter found the belly swollen, sensitive to the touch, especially in the right iliac fossa, and prescribed a purgative of raw salt; the purgative produced no effect. During the day the belly became more swollen and his temperature rose a little (38° C.). The next day another purgative brought no apparent result. From this time forward the state of the patient became alarmingly aggravated; the fever increased, the temperature rose to 39° C. His tongue was dry, and vomiting continued, notwithstanding the ice given to prevent it. At the same time his belly became quite swollen, as in a case of peritonitis (ice was placed on the abdomen). The 18th of November, three days after the beginning of his illness, only one remedy seemed possible,—laparotomy. The patient, being perfectly conscious, was quite resigned to this; but the hospital surgeons, MM. Boutier and Michaut, who were attending him, were afraid to attempt an operation, as the condition of the patient had become very serious: his voice was broken, and his pulse hardly perceptible. M. Larat was called in that night in great haste. They decided that an electric application should be made at once; if it failed, an operation was to take place immediately, for there seemed very little time to lose. Ten minutes later, under the influence of the electric current, the intestine began clearing itself. An abundant evacuation of gas took place, followed by fæcal matter. This discharge continued during the night, and was so abundant that the next morning all the symptoms of peritonitis had disappeared and the patient was convalescent. It must be remarked that some little lark-bones were in the motions, eaten by the patient a few days before, and perhaps these fragments had been arrested by pricking the intestinal mucus, and in this way causing the signs of peritonitis, as well as the symptoms of obstruction.

It seems to me that these two notes prove not only the power of electricity for the treatment of occlusions, but answer also the question raised by some doctors as to whether the electric injection caused peritonitis. If these injections have been able to cure and stop a beginning of peritonitis in two very serious cases, as well as in others similar, how can it be admitted that these same injections could produce peritonitis? Is it not infinitely better, that where, according to the above notes, the development of peritonitis was discovered a few days after the recovery of the bowels, to blame the disease rather than the electricity for which it was applied? In some cases this is most evident; for instance, M. Tripier applied faradic electricity on a patient of Mr. Sée's suffering from intestinal occlusion. He was able to overcome the obstacle and re-establish the course of fæcal matters, notwithstanding some symptoms of peritonitis; but suddenly there was a change for the worse: the patient's countenance had become distorted, and death took place. At the autopsy the intestine showed the vascularization of an ordinary, though not acute, peritonitis, very strongly marked, however, near the cæcum. This

was enveloped in a large abscess, which had broken, and thus inclosed a large quantity of matter in the pelvis.

To end this chapter on contra-indications, we must now ask whether electricity can be blamed for any accident, and especially electric injections? M. Prengrueber, surgeon of hospitals, brought up a case where death seemed to have been the result of an electric application. This is the fact in brief: A patient, 58 years of age, was suffering from a lesion, probably cancerous, which had brought on an intestinal obstruction. The electric injection was applied by an experienced specialist. One litre of salt water was first introduced in the intestine; then, without any difficulty, another litre. The assistants were a little surprised at this abnormal quantity of liquid, but the operation went on without any interruption, and without bringing any result. When the doctor returned to see the patient, five hours later, he was dying; he had been getting worse immediately after the operation. The belly had suddenly become very much swollen. M. Prengrueber supposed that the intestine, consumed by the neoplasm, had burst at the time of the injection, and this had partly penetrated into the peritoneum.

M. Périer, again, told me of a patient at the Hôpital Lariboisière, who was electrified by Boudet, of Paris, and had succumbed. At the autopsy gangrenous slabs were found on the intestinal mucus. That eminent surgeon thought the electric injection had something to do with this complication.

As for the first case, it seems but just to admit that the operator had to contend with quite an exceptional case, and a particularly unfavorable one. Boudet, of Paris, and I, on nearly four hundred cases, have never observed anything of the kind. Besides, the slowness with which it is recommended to introduce the liquid of the irrigator in the intestine seems of a nature to do away with any fear of this kind of accident, which is much more to be dreaded after the forced injections of Seltzer water, so often used.

As for the second case, it is hard for me to admit that the electric injection could have brought on a partial mortification of the intestinal wall. It must be remembered that the intestinal electrode is liquid, and, on account of its mass, represents a considerable active surface. It is even possible to estimate by approximation the ordinary density of current in each square centimetre. Admitting that the water represents an active surface of one hundred square centimetres, which is certainly more than it really does, the intensity used being on an average of forty thousand ampères for each square centimetre ($\frac{0040}{100}$), four ten thousandths' intensity of ampères is very easily stood, and is incapable of producing an appreciable chemical action, and all the more incapable of promoting eschars.

After the electric injection, patients have sometimes complained of a burning sensation and smarting in the anus. This slight irritation is not

caused by electricity, the mandrin being isolated from the ano-rectal mucus by the gum probe. In some circumstances it seems to have been occasioned by the concentrated solution of sea-salt; and in such a case it would be sufficient to use, instead of this solution, water containing salt, such as Vichy water.

I will now lay a stress on the particularities of the treatment. I have said that an immediate result cannot always be expected; in fact, it is often necessary to repeat the applications not only to obtain a first result, but in order to clear the intestine completely. The following notes are good examples of the difficulty of clearing the occlusion in the intestine. For one of these notes we are kindly indebted to M. Moutard-Martin, ex-president of the Academy of Medicine:—

M. L., 57 years of age, had been suffering with obstinate constipation ever since his youth, notwithstanding a life full of activity and a severe diet, living principally on milk food. For the last two years constipation became still more obstinate. M. L. had the habit of purging himself daily, and of drinking two or three litres of milk each day; besides this he took a laxative injection every day. The 30th of May, 1887, M. L. went to the closet as usual. The 31st he complained of uneasiness, of abdominal swelling, and of a feeling of nausea. Dr. Moutard-Martin, being called in, declared a slight dullness in the right iliac fossa and in the ascending colon. Diagnosis: Intestinal obstruction. After this examination, made in the most careful way, without causing any pain, M. Moutard-Martin began writing his prescription, when suddenly M. L. gave a cry of pain; very great suffering had just come on in the right iliac fossa. At the same time the patient felt very anxious and his features became altered. Thinking that an intestinal perforation might have taken place, that at least acute peritonitis had set in, twenty leeches were applied *loca dolenti*, with cataplasms, iced drinks, opium in pills, and hypodermatic injections. In the evening the nausea had ceased, the pain was less, but there had been no evacuation. A consultation was held, at 10 o'clock that night, with Professor Trélat, who confirmed the diagnosis. The following days the local condition was much the same, but a complication occurred on account of the pricking of the leeches; these produced flying erysipelas, without much febrile reaction. The 8th of June the patient passed some gas, and on the 10th, under the influence of an injection, some particles of fæcal matter; this matter was soft and grayish. On the 11th a consultation was held with Professor Potain, who advised them to be patient. The 12th and 13th, evacuations continued, but were very imperfect. In the meantime the flying erysipelas became worse and spread over the body: the buttocks, the left thigh, and a part of the right thigh. On the 13th of June Dr. Moutard-Martin called in Dr. Larat to make electric applications, in order to induce more complete evacuations. By this time there was a much-spread and great dullness of sound in the two iliac fossæ, the belly was swollen, and the general con-

dition bad. As the intestine had been a little evacuated, Dr. Larat thought an external application of faradic current would be sufficient to cause intestinal contractions. He faradized the intestine two days, with no success. He then determined using the electric injection. The movements began after the first application. The ejected matter was discolored and like that of a nursing child. It was evident that the intestine was full of caseum not digested, which had formed a considerable mass near the ascending and descending colon. The patient had seven or eight very abundant motions of the same kind each day from the time of the first electrization, and this during eleven consecutive days. An electrization was made every morning. A singular thing was that, notwithstanding this mass of stercorate matter, the intestine remained permeable. Several times particles of food eaten the day before were found in the motions. The local and general condition of the patient became gradually better, and on June 26th a motion having a natural color appeared, and the patient was restored to good health.

This note is interesting from several points of view. First, its cause: Taking daily a great quantity of milk and repeated purgations having brought on an intestinal atony. Then, the permeability of this stercorate mass must be remarked, in which no doubt a long passage had formed where the matters coming from the stomach passed. Lastly, the great quantity of old stercorate matter contained in the intestine must be kept in mind, and the advantageous results of the electric treatment for this case, already serious in itself, and much aggravated by the complication of flying erysipelas.

M. D., aged 82, had for five or six years great difficulty in going to the closet. He had got into the habit of taking, every day for two years, several Scotch pills, and he had been obliged gradually to increase the dose. The 4th of October, 1888, I was called in by his doctors, MM. Théoph. Anger and Cheurlot. According to these gentlemen, the patient's antecedents were of the very best, with the exception of his habitual constipation, mentioned above; his health had been excellent until just ten days before,—that is, the 24th of September. That day, notwithstanding his usual pills, M. D. did not go to the closet. However, he was not much worried about it; but, after six days of absolute constipation, those around him became alarmed and spoke to MM. Anger and Cheurlot. By this time the patient had not passed any gas or matter for six days; his belly was slightly swollen, and his tongue foul. There was anorexia, and he felt some nausea. Diagnosis: Intestinal trouble. Treatment: Castor-oil purgative. After a few hours this purgative was vomited without producing any effect below. The second of October another purgative was given, with a drop of croton-oil. The medicine was again ejected by vomiting, and this continued the whole day of the 3d, rather in the form of spitting slightly tinted with bile, than in the form of regular vomiting. I saw the patient on the 4th, at

12 o'clock. His digestive organs then appeared extremely torpid; he had taken nothing for several days, and was very much weakened on account of his old age. His pulse was a little quick (90 pulsations); his belly was slightly swollen, not painful. There was no dullness of sound or sensation of puffiness anywhere. A first application of electricity was made at 12 o'clock, without any result. At 7 o'clock another one took place, and this brought forth some matter, but in small quantity and very much diluted; no gas. The condition of the patient remained the same. The 5th, in the morning, another application was made. Some more liquefied matter was ejected, but no gas. However, the patient was better during the day, and felt the spontaneous desire of defecation, which brought no result. A fourth sitting of electrization was administered at 6 o'clock in the evening, and this time successfully, for a decided clearing of gas and some half-solid matter took place; and in the night several abundant evacuations took place, of a very nauseous matter. In the morning of the 6th the general condition of the patient had changed: his pulse was calm and he felt much relieved. However, as a caution, a last application of electricity was made, and a purgative of castor-oil was administered. This had an excellent effect, and during the day there was another considerable evacuation. That evening I thought it unnecessary to make any other applications. To-day the patient has entirely recovered.

These examples prove how much cases differ from each other, and how various are the ways of liberation of the intestine. I will also draw attention to a whole series of cases where intestinal electrization has acted most favorably; I mean for intestinal paresis caused by surgical traumatism of the abdomen. It sometimes happens—and all surgeons who have any experience of laparotomy know this serious complication—that after an operation, often laborious and long, and especially after the intestines have been exposed to the air for any length of time, the belly of the patient becomes swollen, under temperature, bilious vomiting takes place, and the general condition becomes serious. This complication is sometimes a sign that the peritoneum is affected, but it is also often due to a retention of fæcal matters in the intestinal cavity. Under these circumstances purgatives are generally vomited. From its strong action on intestinal contractibility, electrization is often a remedy to this kind of thing, and causes the intestine to resume its functions, momentarily abolished.

Mrs. X., 34 years of age, was operated upon by M. Terrillon for a double ovaro-salpingitis. The operation was rather laborious, but ended without obstacle. For a few days after the operation there was no trouble whatever, but on the sixth day, perhaps on account of an imprudence in the patient's diet, vomiting began, the belly became swollen, and the facies became peritoneal. Several purgatives being administered without any result, M. Terrillon called me in. When I saw the patient

(June, 1892) she had been operated upon eight days before, and had been vomiting almost incessantly for the last twenty-four hours. Her general condition seemed very serious. She was suffering from great pain in the abdomen, although it was not sensitive to the touch. Her pulse was quick and weak (120). M. Terrillon gave the diagnosis of "stercorate" retention and consecutive blood-poisoning. His advice was to apply an electric injection, which I did immediately. An evacuation took place at once, first of gas, then of a rather abundant fæcal matter. The patient had improved the next day; she felt much relieved, her pulse was not so quick (80), and the abdominal pain was not so great. However, as the intestine did not appear to me quite free, I applied another electric injection, which again produced only a partial clearing. Two days afterward, as the improvement continued, we considered the patient saved; but the intestine remained quite sluggish, except when the electric injections were applied, and we thought it necessary to continue the electrization every day until the intestine resumed its natural function. This result was only obtained after nine applications (one each day). By this time the patient was beginning to get up.

Before this I had been called in six times by my master and friend, M. Terrillon, for the same kind of case, with alternate successes and reverses, but we never had any contra-indication to our way of acting in this last operation. I will here end the examples I have given to prove my argument. They seem to me sufficiently convincing, and from the preceding notes we can easily conclude that electric injections, well administered, are exempt from any inconveniences or danger. But we certainly cannot admit that when death has taken place after laparotomy, an electric injection having first been made, it should be attributed to the injection, on account of the latter having put off the surgical operation. It is certain that an operation should be done as soon as possible; but when the diagnosis is not a decided one, how can there be any certainty of medical action being a failure for the case?

We must not forget, as M. Hérard says, in a report made to the Academy of Medicine, that the mortality from laparotomy for cases of occlusion is still enormous, notwithstanding antiseptics. This is not surprising if one reflects on the unfavorable circumstances under which the operation is performed, on account of the stercor; the irritation of the nerves of the peritoneum, which reflects so strongly on the whole organism; the difficulty of examining the viscera of the abdomen, and the danger of malaxation for a distended intestine. After all, what can laparotomy do for rather an ordinary case (thesis by M. Thibierge) of simple accumulation of fæcal matters and intestinal paresis?

Which process should be preferred? A number of observations prove that all electric forms have brought good results; but none can offer so many encouraging examples as intestinal galvanization by means of the electric injection. None are more exempt from all danger. We

think, therefore, that this method should be preferred; but, of course, should the necessary instruments not be on hand, faradization could be used instead. Our most decided and reasonable conclusion is, in fact, that electricity ought to be placed in the first rank among the means that physicians possess to combat this formidable evil. Unfortunately, it must be owned that this means is still too little known and too much disdained.

DISEASES OF THE ALIMENTARY TRACT; DISEASES OF THE LIVER AND KIDNEY; GOUT AND RHEUMATISM.

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DISEASES OF THE ALIMENTARY TRACT.

Stricture of the Œsophagus.—Dysphagia dependent upon organic stricture of the œsophagus offers but little hope of benefit under any form of electrical treatment. The electrolytic action of the galvanic current has been attempted for this condition, but with results by no means satisfactory. Spasmodic stricture, however, affords a different and altogether better prognosis. The diagnosis between the two is not always immediately apparent, but the passage of the bougie will, as a rule, definitely settle the question. Auscultation is also of service in distinguishing between organic and spasmodic stricture of the œsophagus. In the organic form the symptoms develop very gradually, while in the functional variety the spasm is, as a rule, sudden in its onset and paroxysmal in character, having its seat usually in the upper third of the tube. On attempting to swallow, pain is often complained of and the food is frequently ejected, but in the milder varieties the spasm excited by the act of swallowing soon yields and the food passes down. The nervous character of the disease is often evidenced by the influence of the emotions on the character of the symptoms. In one case that fell under my observation the difficulty in swallowing was always greatly increased by expressions of sympathy. As in organic strictures, the introduction of a bougie meets with resistance, but by continuous and gentle pressure strictures due to spasm invariably yield. The few cases of dysphagia from spasm of the œsophagus that it has been my fortune to see and treat have convinced me that electricity, while far from being an unfailing remedy, is often of essential service. It is not infrequently one of the many symptoms of hysteria in women, and in men I have known it to be associated with the neurasthenic state. In such cases every influence of a constitutional tonic character that can be brought to bear upon the system is plainly indicated, and both general faradization and central galvanization have, in my hands, proved more successful than anything else. Localized electrical applications must be attempted on general principles, and especially for the purpose of reducing reflex excitability. The galvanic current is to be preferred for this purpose, although faradization of the peripheral nerves has, in some cases, proved

efficacious. In external applications of the galvanic current, one pole (the cathode) may be placed upon the back of the neck, over the cilio-spinal centre, while the anode is held just above the sternum, or by the inner border of the sterno-cleido-mastoid muscle. If this fail, an insulated œsophageal electrode with a metallic tip should be introduced into the œsophagus to the point of spasm, while the other is placed on the back of the neck. Both currents can be used in this way, but especial caution is to be exercised in the application of the galvanic current, on account of the proximity of the pneumogastrics. It is not inconceivable that overexcitation of these nerves might be attended with serious results. The galvano-cautery has sometimes proved a most effective procedure in these cases after the failure of the ordinary electrical applications.

Some years age Dr. Perry, of Ridgefield, Conn., in consultation with the late Dr. Williard Parker, brought to my office a lady of about 60, with the following history :—

Some months before she had by mistake swallowed a caustic liniment, which resulted in a stricture of the œsophagus believed for some time to be organic. Her inability to swallow food finally became so great that the patient was slowly starving to death, and it became necessary to resort to rectal alimentation. By the introduction of a bougie we finally succeeded, after much effort, in overcoming for a brief space the tonic contraction of the muscular fibres, thus demonstrating that the symptom was entirely spasmodic. Electricity had been tried by various methods, but as yet with no permanent relief, and I suggested that the galvano-cautery be now attempted. Whenever the patient attempted to swallow a spasm was at once excited, associated with intense pain in a limited area of the upper dorsal spine. When the spasm subsided the pain also disappeared. To what extent this condition of the cord was a causative factor in the production of the spasm, or whether it was simply a reflex effect, it was impossible to determine. Certain it is, however, that a single application of the galvano-cautery to the painful spots in the spine immediately and permanently relieved the dysphagia. On visiting her the next morning, I found the patient eating a beefsteak with every manifestation of ease and comfort.

Dysphagia from spasm of the pharynx, although sometimes the result of central disease, is occasionally of spasmodic origin, and may be amenable to electrical treatment. If external applications fail, internal applications may be made by means of a catheter-shaped electrode against the constrictors of the pharynx. In one case of which I have record the difficulty of swallowing was so great that the patient was apprehensive of suffocation. Applications of the faradic current to the constrictor muscles of the pharynx, repeated twice, completely relieved the spasmodic tendency and enabled the patient to eat without fear of consequences.

Paralysis of the Œsophagus.—Hysteria and diphtheria, as well as alcohol and lead poisoning, may cause paralysis both of the œsophagus and pharynx, and in some cases vigorous general and local applications of electricity are indicated. In diphtheritic paralysis especially, electricity is sometimes of inestimable value, yet it should be used with caution.

While diphtheritic paralysis may affect many muscular groups, the patient, as a rule, first notices a slight difficulty in swallowing liquids, and not infrequently the paralysis is limited to the throat throughout its course. The veil of the palate being paralyzed, the food comes in contact with the upper part of the larynx, and occasions violent and alarming coughing. Liquids are ejected through the nose, and swallowing is finally attended with the utmost difficulty. The voice becomes nasal in tone, the muscles of the face expressionless and relaxed, and saliva dribbles from the mouth. According to the degree of the paralysis of the palate, pharynx, tongue, and lips, is the speech affected, becoming at times so difficult and thick as to render the utterance almost unintelligible. The natural tendency of diphtheritic paralysis is toward recovery, yet there can be no question but that recovery is in many cases greatly accelerated by judicious and vigorous treatment, electrical and otherwise. The rapidity of the progress toward recovery depends not a little upon the condition of the function of nutrition. If this is performed imperfectly, the paralyzed condition may drag along for months instead of weeks; secondary conditions such as nerve degeneration and muscular atrophy supervene, and the paralysis becomes permanent.

To aid nutrition, then, in every way possible is of the utmost importance in every one of these cases. In diphtheria, the asthenia and anæmia are perhaps more profound than in almost any other disease, and during convalescence and for the loss of the muscular power there is no remedy that better promotes nutrition and the healthful exercise of all the functions than electricity. For this purpose, general faradization is mainly indicated, although for the local trouble the applications may be made directly to the pharynx by means of a pharyngeal electrode.

I decidedly prefer the faradic to the galvanic current in these cases, although both are of value. If the latter is employed, it should be used *not* to excite contractions in the paralyzed muscles, as is so often advised, but without interruptions. In this way it exerts a more beneficial influence over nutrition, and has no tendency to exhaust the returning power of the affected muscles. The peculiar mechanical effects of the faradic current seem to exert a special influence over diphtheritic paralysis wherever located, and greatly accelerates the progress toward recovery.

Dilatation of the Œsophagus.—The œsophagus may become dilated through its entire length, although more frequently only a portion of the tube is affected. In connection with the more or less symmetrical dilatation involving it, sacs or diverticula are sometimes formed, which add greatly to the gravity of the case.

A simple idiopathic case of dilatation of the œsophagus, involving the whole of the tube, may exist unattended by symptoms of grave or even special importance; but a local dilatation dependent upon stricture, or associated with diverticula, presents symptoms both serious and distressing. The patient experiences a sensation of fullness in the tube,

associated with a desire to vomit which, if induced, affords marked relief. This fullness is oftentimes so marked that it can be readily seen and felt. The food is necessarily to a certain degree retained in these pouches, and its decomposition renders the breath exceedingly offensive. As might be inferred, the peristaltic action of the muscular coats in cases of dilatation is sadly interfered with and the food, instead of being gradually conveyed to the stomach, seems to drop suddenly down, meeting neither with resistance nor assistance. Altogether, the disease, although infrequent, is most annoying, and ordinary methods of treatment have proved quite useless excepting in those cases where it has been directly dependent upon some removable cause. The use of electricity somewhat improves the prognosis, yet the results are not very encouraging.

The simplest method is to introduce the current by percutaneous application, for even when sacs complicate the case improvement has been known to follow. The method, however, that promises most is the introduction of an œsophageal electrode for the purpose of directly stimulating the œsophageal muscles.

In external applications the faradic current of tension is to be preferred; but if no results follow, the galvanic current may be substituted. In internal applications, and especially if the bipolar form of electrode be used, the faradic current of quantity will prove far more efficacious in producing contractions of the muscular fibre than currents of tension.

Gastralgia.—Much difference of opinion exists concerning the cause and character of this distressing disease. Neuralgia of the stomach is undoubtedly associated with, and is an expression of, a variety of pathological conditions. The slight heaviness or fullness after taking food, characteristic of chronic gastritis, hardly amounts to a neuralgic pain, but in atonic dyspepsia sharp, shooting pains are frequently complained of. Both ulceration and cancer of the stomach cause the severest pain, and are susceptible only of slight relief through electricity. Chronic catarrhal gastritis, occurring in the gouty subject, is another cause of gastralgia, for the relief of which dependence must be placed upon remedies other than electricity. Experience clearly shows, however, that there does exist a form of gastralgia dependent neither upon inflammation nor organic disease, entirely functional in character, and relievable by very much the same methods as neuralgia in other parts of the body. Electricity enables us not infrequently to diagnosticate between gastralgia dependent upon organic changes in the stomach, such as ulcer, beginning carcinoma, etc., and gastralgia in which the purely nervous character of the affection is not doubtful. A case in point occurs to me:—

Some years ago I was consulted by a gentleman for a severe pain in the stomach that had persisted for more than six months. The character of the pain was suspicious, and he had been told that the cause of it was ulceration.

As in pain from that cause, so the pain in his case was referred to one spot in the

epigastrium and in the back. When the stomach was empty but little, if any, pain was experienced, but in a very few moments after eating the distress was often extreme. The first application of electricity was made at the beginning of a severe paroxysm of pain, and within five minutes it disappeared completely. This result indicated very clearly to my mind that we were not dealing with an ulcer, for, in a number of cases of that character which had fallen under my observation, every one had failed to be relieved by any form of current.

It is not to be expected that this aid to differential diagnosis never fails, for gastric neuralgias frequently resist the action of the current as do other neuralgias. When, however, it does relieve as promptly as in the case just referred to, its diagnostic value is undoubted. In treating gastralgia both forms of dynamic electricity have proved effectual, and in the selection of the current one must be governed by the special indications in each individual case. Not infrequently, indeed, it will be found impossible to determine which form of current is best adapted to the case in hand until actual trial is made.

In a considerable experience, however, in the treatment of gastralgia I have found that in those cases where firm pressure over the seat of pain tended to relieve rather than to exaggerate the pain the faradic current of high tension yielded the best results. On the contrary, when the part was sensitive to pressure, pain being increased rather than relieved, the galvanic current generally proves most effective. In one case of gastralgia in which the faradic current was indicated, but which failed to accomplish very much, a rapidly-interrupted static induction current succeeded in affording complete relief. In using the galvanic current I prefer electrodes of plastic sculptors' clay, placing the anode over the seat of pain. In this way currents of 20 to 25 milliampères are readily borne.

Atony of the Stomach.—The integrity of one's digestive powers depends upon the tone of the muscular tissues of the stomach, as well as upon the healthful action of the nerve-centres and connecting nerves. The vast majority of cases of confirmed indigestion for which relief is sought depend upon no structural change in the stomach, but are occasioned by a deficient secretion of gastric juice or a defect in the muscular tone of the organ. The resultant feebleness of the organ lessens the activity of the characteristic churning movements that attend the digestive process, and the first act of digestion is unduly prolonged. Atonic dyspepsia is sometimes hereditary, and in such cases tends to manifest itself rather early in life; but where no hereditary tendency exists the disease is more apt to show itself late in life. Like all other organs, the physiological activity of the stomach declines as years increase, and dyspepsia among the aged is a common symptom. Among the rich who suffer from atonic dyspepsia the cause is usually to be found in an undue amount and undue frequency of food.

It is hardly necessary to say that errors of diet are the common causes of impaired digestion. Frequently, under the mistaken idea that

conditions of debility must be corrected by the frequent and large ingestion of food, the stomach is never allowed a sufficient period of repose. Among the poor, as well as the rich, however, this form of indigestion is by no means uncommon. Innutritious as well as insufficient foods are potent causes of atonic dyspesia, the cure for which would be, in many cases, simply a more generous diet. Anything, indeed, that interferes with the secretions of the stomach or with its muscular action tends to weaken the function of digestion. Atonic dyspepsia, therefore, is often associated with any chronic discharge, such as leucorrhœa, and it is not uncommon to find anæmia and indigestion closely allied. Atonic dyspepsia is seldom attended with acute pain.

As a rule, the disease develops very gradually, about the first symptom observed being more or less flatulence, associated with a feeling of distension after eating. The distended stomach may also interfere with the action of the diaphragm, and occasion more or less dyspnœa. Eructations are common and annoying, but vomiting is seldom observed. The appetite in this disease may finally become greatly deficient, and sometimes there is an absolute aversion to food. Impaired digestion, long continued, is often associated with the most marked functional disturbance of the heart that manifests itself most violently at night. The pulse is often slow and feeble, and the extremities cold. Constipation is a pretty constant symptom, and loss of flesh and strength is almost necessarily an accompaniment.

Organic diseases are, as a rule, readily distinguished from this functional disturbance. But it becomes more difficult to differentiate between atonic dyspepsia and certain inflammatory affections of the mucous membrane. A diagnostic point of importance is the epigastric tenderness which is almost invariably associated with inflamed conditions of the gastric mucous membrane, while in cases of indigestion due to atony pressure causes no pain. Neither acidity, heart-burn, nor vomiting are common in atonic dyspepsia, as in gastritis. While, in inflamed conditions of the stomach, the urine is high colored and loaded with lithates, in atonic conditions it is rather pale in color and deposits oxalates or phosphates. Although electricity is only one of many remedies that may be indicated in atony of the stomach, yet an abundant experience in the treatment of this condition justifies me in placing it in the front rank of our therapeutic resources. Manifestly, the indication of primary importance is to remove, as far as possible, the causes of the disease. Whatever is injudicious in the quantity or quality of the food or the frequency with which it is taken should be corrected and the patient instructed as to proper methods of living. If he continue to masticate his food imperfectly, eating too much or too little, or persist in indolence or luxurious methods of living, neither drugs nor electricity will avail.

In connection with proper hygienic methods, I have known elec-

tricity to help on rapidly, in many cases, to a greatly improved condition of health. Whether the defects of digestion depends upon an exhausted condition of the nervous system interfering with the normal activity of the processes of excretion and secretion, or whether the blood-supply is deficient in quantity or abnormal in quality, the well-attested action of electricity in modifying the physiological functions of the body renders it the most efficient of remedies. The tendency of electricity is both to increase secretory processes and to modify their quality. The secretion of the gastric juice and of the intestinal fluid has been shown to be increased by external electrization. Even without demonstration, analogy shows that these fluids ought to be secreted in greater abundance, under the influence of the current, and the results of the treatment in pathological cases give this probability the force of certainty. Appetite is sharpened, digestion is quickened, and constipation relieved, both by local and general electrical treatment, so rapidly and so decidedly as to make it pretty evident that the gastric and intestinal fluids are made to secrete more liberally by the action of the current on the nerves that supply these organs than on the tissues of the organs themselves. An excellent means of studying the variations in the nutrition through electrization is found in the elimination of urine. This is believed to be a result of oxidation processes that may take place either in the kidney or in the tissues, or in both. Animal nutrition is a process of enormous complications. There is no single chemical change at which one can point and declare that this explains the growth and sustenance of the body; but there are nameless and numberless phenomena every moment going on in the living tissue, and, as a result of these, in their infinite play and combination, the body lives, moves, and has its being. Electricity, in passing through the body, modifies many or all of these processes, and thus modifies nutrition.

As a resultant of the complex physical, chemical, and physiological action of electricity on the tissue, there is increased development and growth. The faradic current of rapid interruption and high tension yields results superior to the galvanic in the treatment of atonic dyspepsia. In the use of the faradic current the treatment must be both general and local. General faradization is pre-eminently indicated in the affection not only for its direct, but for its reflex effect upon the supply of the stomach. Internal applications are seldom if ever indicated in atonic dyspepsia.

In the use of the faradic current the electrodes should be sufficiently large to prevent any undue concentration of current, and instead of being stationary the pole over the region of the stomach should be kept in almost constant motion. In this way and by the exercise of care it is quite easy to avoid those painful muscular contractions that so frequently occur.

Through inattention to this simple precaution, I have on more than

one occasion seen the most violent and prolonged tonic spasm excited, exhausting the patient and discouraging him from further attempts in this direction. The continuous or unbroken action of the galvanic current, notwithstanding its usually good effects in the promotion of nutrition, seems to be of little service in atony of the stomach. The direct mechanical action and the indirect reflex effects of a mild galvanic current, rapidly interrupted by means of a rheotome, however, is undoubtedly of service, although inferior in its therapeutic effects to the induced current of high tension.

Paralysis and Spasm of the Stomach.—These two irregularities of the mechanism of digestion may be either of central or peripheral origin. The peristaltic action of the stomach may be impaired or practically lost through a diseased condition of the nerve-centre where the motor stimuli originates; but more frequently, it is believed, paralysis of the stomach is caused by disease of the nerve-fibres which convey these stimuli. Again, it is entirely possible that both paralysis and spasm may be due to lesions of the muscular tissue itself.

The peristaltic movements of the stomach are in greater or less degree dependent upon the integrity of the vagus nerve, and whatever method of living or accident of disease interferes with its accelerating influence must necessarily interfere with these peristaltic movements. Exhausting fevers, prolonged vomiting, and hysteria have been followed by this condition, and excessive mental strain must not be omitted in the consideration of its causative factors. Inflammatory disease of the mucous coat of the stomach interferes with its contractility as well as degeneration of the organs. In paralysis of the stomach, unlike dilatation, it is rarely necessary to apply the current directly to its walls. If external applications fail, internal treatment will be very liable to prove fruitless also.

The faradic current is best utilized by applying a large electrode a little to the left of the spinous processes, and at a level with the cardiac end of the stomach. The other electrode, by preference the cathode, is applied successively with constant movement over the entire surface of the gastric region. The galvanic current might also prove of service, and, as in the treatment of atony of the stomach, the current should be a mild but rapidly interrupted one.

Spasmodic affections of the stomach depend upon many causes, are usually tonic in character, and are accompanied by pain, sometimes of the most distressing character. Whatever the cause, we have increased irritability of the nervous and contractile tissues, leading to severe spasm upon the slightest cause.

Spasm may be limited to the cardiac orifice of the stomach, and is here supposed to be due not to stimulation, but to the want of it. This is evident from the fact that, if the vagus be divided the opening closes and remains closed until the peripheral end of the cut nerve is arti-

ficially stimulated. The investigations of Schiff go to show that the vagus supplies a nerve-twig which regulates the opening of the cardiac. "The cardia is richer in ganglia than the stomach itself, there being twelve in the former and only ten in the latter; this richness in nervous matter almost entitles it to be called the 'brain' of the stomach. The different parts of the cardiac orifice are functionally independent of each other, and one half may be in a state of contraction while the other is relaxed." Theoretically these forms of spasm ought to be benefited by electricity, and the galvanic current would seem to be indicated above the faradic. In cases of spasm the indications are for an application of the current of increasing strength without interruptions. With electrodes of moist clay, one pole, the anode, may be placed over the epigastrium, and the other applied along the spine from the nape of the neck to a point on a level with the cardiac orifice of the stomach. Strong currents, even as high as 40 milliampères, can be used in some cases. In my own experience spasm of the stomach has been most relieved by applications of the galvanic cautery to the spine.

Chronic Dilatation of the Stomach.—The efficacy of electricity in this condition depends, manifestly, very much upon the cause. Unfortunately, the etiology of chronic dilatation of the stomach is too frequently dependent upon diseases that are beyond the reach of either medical or surgical interference.

Cancers, fibroid thickenings, and ulcers—for all of which, situated as they are, electricity is of doubtful value—are the frequent causes of dilatation. Other causes of dilatation by no means unknown are paralysis of the muscular walls of the stomach and chronic catarrhal gastritis, both of which clearly indicate electrical treatment. Following catarrhal gastritis dilatation comes on very gradually, accompanied by comparatively little pain, but with sensations of weight and fullness that cause great discomfort. Ordinarily it is not difficult to diagnose a dilated stomach. The abdomen is irregularly distended and a tympanitic sound is elicited over a wide area. The left side of the abdomen is fuller than normal, and in these persons the vermicular motion of the organ may be distinctly apparent.

The following case illustrates not only the symptoms that may exist in connection with chronic dilatation of the stomach following chronic gastric catarrh, but the part played by electricity in its treatment:—

The patient was a gentleman aged 40, with the following history: Some five years previously he had an attack of acute gastritis, from the effects of which he never seemed to have perfectly recovered, although for two years after the attack he was very much better than he has been latterly. Three years ago he began to experience an unusual amount of acidity, accompanied by a burning feeling that extended from the stomach to the throat. Finding that stimulants temporarily relieved these symptoms, he resorted to them, only to find that their ultimate effects were bad. The patient likened the sensation in his stomach to the process of fermentation, and, while nausea was not generally complained of, yet occasionally he would be attacked with severe paroxysms of vomiting, after which he would

feel greatly relieved for several days. The acid eructations were especially distressing; and this symptom was most difficult to modify, from the fact that his appetite was at times simply voracious. His assimilative powers, however, were impaired to such a degree that he lost flesh little by little, until at the time he came for treatment he was greatly emaciated and physically exhausted. The bowels were obstinately constipated and the urine was loaded with lithates. An examination of the abdomen revealed some of the characteristic features of the disease. The upper curvature of the organ and the left side of the abdomen were more prominent than normal, while the epigastrium was greatly sunken. Percussion readily elicited the tympanitic sound even after the ingestion of food, but became especially resonant and pronounced an hour or two after vomiting. In the treatment of this case remedies other than electricity were employed, but the latter therapeutic means constituted the main reliance, from the fact that many other methods, including washing out the stomach, had been persistently tried long before.

It was evident that the indications in this case were mainly two: 1. To restore the tonicity of the overworked and exhausted gastric muscles. 2. To give tone and strength to the general system. To accomplish the first object applications directly to the interior of the stomach were attempted, and this was rendered the less difficult from the fact that, at the recommendation of Kusmal, whom he had consulted some years before, he had become quite expert in introducing a tube and washing out his stomach himself. I did not use the ordinary unipolar, but a bipolar electrode.

As a matter of precaution, I employed the faradic current of tension; but partly because of its inefficient action when used in this way, and partly, perhaps, because of the greatly lessened sensibility of the organ itself, the current was felt only slightly, and after two weeks of trial I abandoned it for the induced current of quantity. I may say, in passing, that I did not very confidently anticipate satisfactory results from the first efforts made, but tried them in order to satisfy myself as to the relative efficiency of induced currents of quantity and tension by the method of bipolar faradization when applied directly to the stomach. I wished to determine whether the same differences in the two qualities of current were observable as when applied to the uterus and vagina.

The only effect that could be regarded as at all beneficial was a little less acidity and decreased burning sensation at the cardiac orifice of the stomach and along the œsophagus. The current that I now used was of such slight tension that when passed through the hands of the patient it caused but slight sensation, and muscular contractions that were hardly perceptible. Localized, however, through the bipolar electrode, directly against the inner surface of the stomach, the effects were immediate and positive. Not only was more or less pain experienced, but an evident contraction of the muscular tissues of the stomach. These supposed contractions were not visible, but the patient compared the sensation to that of vigorous contraction. It was not possible, as in the use of currents of tension, to greatly increase the strength of the current. What was painful in the beginning continued painful throughout the application.

The results of this local treatment, combined with general faradization, were in this case really remarkable. A considerable time elapsed before the patient even approximately recovered the normal tone of his stomach, but his varied symptoms began to amend immediately. The most marked and grateful relief, of which the patient could not speak too often, was the disappearance of that feeling of intense heaviness of the stomach, associated with a sensation as if the contents were undergoing fermentation. The vomiting also ceased in time, and the appetite, which at times became so voracious that he found it all but impossible to control it, gradually became quite normal, and, as a natural sequence, improvement in strength and flesh kept pace, until at the end of three months the patient had increased in weight from 117 to 145 pounds.

While I prefer the bipolar method in the intra-ventricular treatment of dilatation of the stomach by electricity, the electrodes devised by Bardit[1] and Einhorn[2] are of decided practical value. It is not always easy to introduce an electrode which must be guided by the hand of the operator along the œsophagus to the stomach. In the case mentioned above it was no difficult matter, since the patient had become accustomed to the use of the tube for lavage, but in other cases the retention of a thick, unyielding tube in the throat during an electrical *séance* causes most unpleasant sensations, and frequently becomes unbearable.

Einhorn's electrode consists of a small metallic conductor surrounded by a hard-rubber capsule or covering perforated at many points. This electrode is attached to a very small insulated tube, easily flexible, and containing the conducting wires. This most patients can swallow with a little effort and practice, and if the stomach is partially filled with water beforehand the fluid acts as a conductor, and the coats of the stomach are not subjected to the direct action of the current. With this form of electrode the unipolar is, of course, the only method that can be used, and where our object is to stimulate the secretory action of the stomach it is all-sufficient. When, however, we desire vigorous motor stimulation, as in many cases of dilatation of the stomach, it has not, in my experience, served so good a purpose as direct applications with bipolar electrodes. It is unnecessary to say that in these applications the current should be carefully graduated and the greatest care exercised in the introduction and manipulation of the electrode.

With these precautions I have been enabled to treat a number of cases of dilatation with positive advantage, and without any ill effect resulting from direct contact of the electrode with the mucous membrane of the stomach. The action of electricity in exciting the gastric secretion has been well shown by Einhorn. Several cases in which he was unable to detect any trace of hydrochloric acid after test meals he subsequently subjected to internal faradization, with the result of readily finding free hydrochloric acid in each case.

[1] Bull gén. de Thérap., 1884, t. 106. [2] Medical Record, May 9, 1891.

Hyperæsthesia of the Stomach and Vomiting.—Both of these symptoms are not infrequently the expression of some neurotic condition entirely independent of any real gastric disease. As an accompaniment of ulceration, hyperæsthesia of the stomach is manifestly beyond the range of electrical treatment, and for this very reason electricity becomes in some cases a not unimportant aid to diagnosis.

An unmistakable evidence of its importance was afforded in a case that lately came under my observation. This patient had consulted many physicians for the relief of various dyspeptic symptoms, but was more especially distressed by an exquisite sensitiveness of the stomach that finally led to the belief that some organic disease existed. Among other conditions ulceration had been diagnosed, and the patient came to me with that idea firmly fixed, and, in consequence, had received more harm than good from a persevering adherence to a liquid form of diet, and from frequent doses of opium. I was not prepared to offer any definite diagnosis, but in view of his generally weak and anæmic condition a ferruginous preparation, combined with arsenic, was given; and, in connection with general faradization, the galvanic current (strength 10 milliampères) was localized over the area of pain. Marked alleviation followed even the first application, and the ultimate result was an approximate recovery. Ulceration, in my experience, cannot be relieved in this way, and it is seldom, if ever, the case that any organic disease of the stomach receives more than temporary benefit from any method of electrization. Among neurasthenics, both men and women, this symptom is not infrequently observed, and for its direct and immediate effect electrization is undoubtedly the most efficacious of all remedies.

Vomiting, like every other symptom, depends upon such a variety of causes that to say that electricity is good for it is true only in a very restricted sense. It is, indeed, in most cases of doubtful etiology, difficult to discriminate between those cases that can be and those that cannot be benefited by electricity. This much may, however, be said, that the cases of vomiting that receive marked benefit from electricity are neurotic cases, and that these cases are, as a rule, unattended with nausea. I have known vomiting in the hysterical and neurasthenic patient to be alleviated by electrization as readily as when it existed as a symptom unassociated with any constitutional disturbance. General faradization, central galvanization, as well as direct applications to the stomach, have all occasionally proved efficacious in my hands, but one case which had resisted all of these methods yielded to an application of the galvanic current directed from the nape of the neck to the pit of the stomach. In a gentleman otherwise apparently well, the food was rejected without nausea every morning immediately after breakfast. By applying electrodes, one at the cilia spinal centre, the other over the solar plexus, and using currents up to the point of endurance, from 40 to 60 milliampères, the habit was entirely overcome. The use of electricity in the vomiting

of seasickness has been of seeming value in some cases, and is, perhaps, deserving of further trial. Seasickness is not really a disease of the stomach, but of the central nervous system probably, and the vomiting, although a frequent, is by no means a necessary, symptom.

Paralysis of the Intestines and Constipation.—The peristaltic action of the intestines may be greatly impaired or entirely lost through a variety of causes. The nervous system may be at fault, the muscular fibres of the intestines gradually losing their contractile power from defective innervation.

From the fact that there are no recorded observations indicating structural changes in the nerves supplying the muscular coats of the intestines or their intrinsic ganglia, it is fair to conclude that the defective innervation referred to above is either entirely functional in character or due to some disease of the central nervous system that interferes with the function of the vagi. It is entirely probable also that disease of the spinal cord itself may produce intestinal paralysis.

Paralysis of the intestines, however, is probably more often the result of degeneration of its muscular tissue, the causes of which are manifold. Granular changes take place in the muscular fibres during the progress of inflammation of the mucous or serous coats of the intestines. The frequent and injudicious use of powerful purgative medicines is a very common cause of paralysis of the peristaltic movements of the intestinal tract, as well as the constant dilatation the result of retained fæces. Besides these there are constitutional causes that act as potent factors in weakening the irritability of the muscular tissue.

Constipation as a sequela of various acute diseases is by no means uncommon, a condition which is simply the expression of a diminished peristaltic action. Typho-malarial fever, diphtheria, violent attacks of hysteria, and an imperfect nutrition for lack of proper food all result in a depreciation of the tone of the nervous and muscular system that in some cases very seriously interferes with peristaltic movements. In a certain proportion of cases of this character electricity is of positive service, accomplishing more perhaps than most other methods of treatment. Both the galvanic and faradic currents may be used, but my preference has been and is for the faradic. Its powerful mechanical and limited reflex effects seem to be better adapted to restore the impaired irritability of the muscular coats. In the intestinal paralysis due to distension from retained fæces and from the action of powerful cathartics, the best results are obtained through internal applications, sometimes by the unipolar, sometimes by the bipolar method. In the unipolar method, one pole, preferably the anode, is introduced into the rectum, while the other is applied externally to every part of the abdomen as well as to the dorsal and lumbar regions of the back. If the galvanic current is employed the cathode should invariably be placed internally, the extent of the introduction depending upon the necessities of each

individual case. The strength of the galvanic current should hardly exceed 2 or 3 milliampères even when used with constant interruptions, but when used continuously without interruptions 1 or at most 2 milliampères are amply sufficient. The strength of the faradic current may be safely left to the sensations of the patient.

Whatever can be borne without great discomfort is safe to use. To those who understand the exceedingly powerful influence of an induction current of quantity, when applied to surfaces that offer little resistance to its passage, it is at once evident that it is to be greatly preferred to currents of tension in exciting intestinal muscular contractions. In order that the resistance may be reduced to its minimum, both poles should be introduced into the bowel, using for this purpose a bipolar electrode. Induction currents of high tension, when applied to mucous surfaces, act mildly both on motor and sensory nerves. Indeed, so tolerant do these parts soon become to such a current, that, even when the strength is very great, the patient may be entirely unconscious of its passage. The induction current of quantity, on the contrary, requires the exercise of the greatest caution. Excessive pain is occasioned by strong applications, and the parts do *not* become tolerant to its influence as the application continues. Impaired peristaltic action dependent upon constitutional conditions, the result of either acute or chronic diseases, demand more than mere local treatment. In addition to this local treatment with the induction currents of quantity and by the bipolar methods, and more often entirely superseding it, the treatment by general faradization [1] is, beyond all question, productive, in many instances, of the most beneficial results. For this purpose, currents of comparatively high tension are required, and, when thoroughly and judiciously applied, the method is efficient to increase the processes of waste and repair, improving nutrition and imparting tone to the system generally and locally.

In an article on the use of the galvanic current as a laxative, Dr. John V. Shoemaker (*Medical Bulletin*, June, 1890) claims good results in the treatment of constipation by the use of the following method: The intra-rectal rheophore, representing the negative pole, is introduced to the usual distance in the rectum and the positive electrode pressed against the perineum. He says:—

> The strength of the current should be about that of 1 milliampère, rather less than more, so that the patient will feel at first as if no current at all is passing. In the course of fifteen or twenty seconds, however, he will begin to feel it gradually rising from the cold of the olive-shaped rectal electrode to the warmth of the same object, gradually heated to a point of painless tolerance. The slowness of the increase, as well as its steadiness, seems to be a factor in the success of the result sought. Shock, or even abrupt transitions in the strength of the current, seem to be prejudicial to success. The perfect confidence of the patient, derived from the certainty that the process will be gradual, and cannot be

[1] For a detailed description of the author's method of general faradization, its *modus operandi*, effects, and *rationale*, the reader is referred to Beard and Rockwell's Treatise on the Medical and Surgical Uses of Electricity. Eighth edition. Wm. Wood & Co., publishers, New York.

startling at any point, conduces to the result. Every one knows how important undisturbed repose is to the successful evacuation of torpid bowels. In about a minute after the application of the current the sensation of desire to go to stool becomes manifest, and, at the end of two minutes, the average patient can generally be affected to the degree requisite to secure a pleasant passage. I think that this process can, by repetition, be made to have constitutional effects in the alleviation or removal of chronic constipation. Of this, however, I affirm nothing, but merely throw out the suggestion, without assigning my reasons for thinking that the effect may be made more or less permanent.

Two phenomena attend the administration of the continuous current in the manner in which I have described. They seem to point to two, at least, of the efficient causes of the chief effect observed: 1. Depending upon the position of the fæces, an unmistakable trickling in the rectum is perceived. 2. If the pole at the perineum be quickly removed, the sphincter of the anus forcibly contracts. The conclusion, therefore, is inevitable that, as to the first, a general discharge from the mucous membrane is stimulated; and, as to the second, that the whole of the rectum and the lower portion of the bowels are dilated, both superinduced conditions working to the desired result.

The internal electrode should invariably be attached to the negative pole of the battery.

Chronic Diarrhœa.—Shortly after the late civil war the attention of the writer was very forcibly called by a number of suggestive cases to the value of electricity in conditions of chronic diarrhœa. Among the soldiers, exposed to the unusual hardships of the field and the unsanitary conditions of camp-life, diarrhœa was attended with an unusual degree of fatality and frequently merged into a chronic condition, from which the intestinal tract never entirely recovered. In many of these cases the symptoms, even from the beginning, would present all the characteristics of chronic diarrhœa, with absolutely no acute stage.

Chronic inflammation and ulceration, varying greatly in extent and severity, evidently existed as the pathological condition in most of these cases, as in most other cases of chronic diarrhœa, and the termination seemed to be almost inevitably fatal. The ulcerative process, which is generally located in the colon, usually renders the stools alternately liquid and solid, and results in a general impairment of nutrition and a greater structural alteration of the tissues involved. The appearance, even, of a person suffering from chronic diarrhœa due to intestinal lesions is so distinctive as to become in some cases almost pathognomonic. The patient is almost invariably greatly emaciated; his complexion of a peculiar muddy character, and with these is associated a marked degree of hypochondriasis. The mental movements in these cases are often observably dulled and slow, associated with extreme irritability, and a short, dry cough that might lead one to suspect lung disease. While chronic enteritis is said to be almost invariably fatal, yet, under persistent electrical treatment, I have known unmistakable cases of the disease, presenting all the symptoms enumerated above, to approximately recover. General faradization, combined with prolonged and frequent applications to the abdomen and back, seems to have not only a most invigorating effect upon the system at large, but a direct local effect upon the diseased parts themselves.

It is possible that direct applications to the diseased surfaces in these cases might prove of service, but in most instances it is difficult to accurately locate the parts desired to be acted upon ; and even if it were possible, they are, as a rule, not readily accessible.

Stricture of the Rectum.—From the stand-point of its electrolytic action, the galvanic current has been advocated, and to a certain extent used, in cases of rectal stricture. The published reports have not as yet been sufficiently conclusive or convincing to enlist general confidence in it as a remedy for this condition, although there is really much less objection to the use of electrolysis in the rectum than in the urethra.

Stronger currents can be used, thus increasing the probabilities of success, and there is much less danger of seriously injuring the parts than in the treatment of urethral stricture. The following is a report of an apparent cure of a very marked stricture of the rectum, which had existed several years, and, in spite of a linear proctotomy, had contracted so as to admit only a small silver probe :—

The cathode was applied directly to the stricture, at intervals of a week,—eight applications in all. The electrolytic application at each visit was fifteen minutes in duration and the number of cells used (chloride of silver) from ten to fifteen. It is unfortunate that the number of milliampères were not given, since, for obvious reasons, the mere statement of the number of cells used conveys no accurate information as to the actual strength employed.

DISEASES OF THE LIVER AND KIDNEY.

Hyperæmia of the Liver.—Acute hyperæmia of the liver is not usually of very serious import. Through rest, attention to diet, and a free operation of the bowels the attack can, as a rule, be cut short and complete recovery assured. Repeated acute attacks of congestion, however, may finally result in a condition of passive hyperæmia, which, if not relieved and the normal functional tone of the liver restored, will, in its turn, degenerate into an atrophic or cirrhotic state. The variation in the size and tenderness of the liver in conditions of hyperæmia, whether active or passive, varies greatly. In some cases the organ is found not to be enlarged to any appreciable degree, while in severer cases, especially those due to an obstructed circulation, the liver can readily be distinguished by the touch far beyond its normal limits. In acute cases there is often great tenderness on pressure, but in chronic cases this tenderness is not so marked. In nearly all cases, however, the patients will complain of more or less fullness and oppression on the right side and over the stomach. In the greater number of cases of chronic congestion of the liver that have come under my observation

there have existed marked functional disturbances elsewhere. A furred tongue is generally present, and nausea and even occasional attacks of vomiting add to the general discomfort. The acrid bile secreted sometimes occasions a diarrhœa of a peculiarly griping and distressing character. Headache is a very common symptom, but the condition which is, perhaps, more constantly present than any other, and which is the source of most distress, is the profound depression of spirits proverbially associated with any form of liver inefficiency. The active congestion of the liver, dependent upon overeating and drinking in persons of sedentary habits, must be met and overcome by properly-directed dieting and adequate exercise. Electricity is, in this class of cases, of little value so long as there exists a disregard of hygienic methods of living, although the mechanical effects of the faradic current may in some degree act as a substitute for active exercise. When, however, active hepatic congestion follows, and is caused by suppression of the menses, there is hardly a remedy that acts with greater promptness and efficiency than electricity.

A case like the following has, in my own experience, been not infrequently observed :—

A woman, generally of plethoric habit and nearing the climacteric period, seeks advice and relief for a feeling of oppression and tenderness over the region of the liver and stomach. The pain is generally slight, but the sense of fullness complained of is so constant as to be terribly wearing. Many other symptoms, such as headache, drowsiness, depression of spirits, and constipation, are present, and in many cases the irregularity of the heart's action is of the most pronounced character. The urine is almost invariably high-colored, and in other ways changed in character. The patient will tell you that the menstruation ceased suddenly, or failed to appear at the usual time some months before. The objective symptoms elicited by percussion may or may not be pronounced, but in some cases, and in one especially of recent date that I recall, the liver had attained a considerable size. In this case electricity wrought a speedy and complete recovery, not so much by the general methods of application, which are often so effective in the relief of local congestions, but by applications directed to the uterus itself, thus re-establishing the suppressed menstrual function. First, a bipolar vaginal electrode was introduced and the faradic current of quantity applied; this proving ineffectual, the intra-uterine bipolar electrode was used, and after a few *séances* was followed by a menstrual flow of the most profuse character. The relief thus afforded was very great. The tenderness and fullness in the right side ceased to cause annoyance until the time for menstruation again came round, when, with the non-appearance of the courses, she again began to suffer. A repetition of the same method of treatment once more resulted in bringing on the courses, less profuse than before, but attended with the same grateful relief. The next menstruation came

on without forcing measures, and the case passed from under my observation apparently cured.

Congestion of the liver due to mechanical causes are manifestly beyond the range of electrical treatment. Indeed, when there exists an impediment to the circulation of the blood from the liver to the heart, due to dilatation of the latter organ, or when the congestion is caused by disease of the lungs, obstructing the circulation in the pulmonary arteries, all remedies, as a rule, prove of little permanent avail. There is one cause, however, of chronic or passive hyperæmia of the liver which is often exceedingly persistent, but yet at the same time susceptible of relief, not only through medication and hygienic methods, but especially by electrization.

After exhausting fevers of the typho-malarial type, puerperal fever and the acute exanthemata, there remains an impaired condition of the general system, of which the most prominent manifestation is a weak and irritable heart, that either causes or keeps up a chronic state of engorgement of the liver. General faradization is, in these cases, of undoubted service. With one pole at the cilio-spinal centre and the other at the feet, or the buttocks, or the solar plexus, a powerful induced current of tension can be applied, sufficient to affect the sympathetic system of nerves and the pneumogastric, and, through these, the heart itself, as well as the arterial ramifications.

Diseases of the spleen, especially leucocythæmia, frequently result in enlargement of the liver, but associated at first with no structural change other than congestion. The anatomical relations of these two organs are so intimate as to readily occasion complications. The splenic and the portal veins open into each other, and morbific influences are easily transmitted from the liver to the spleen, and *vice versâ*. In consideration, therefore, of the fact that out of ninety-two cases of leucocythæmia collected by Ehrlich the liver was found to be diseased in fifty-four cases, treatment directed to the spleen alone may benefit its fellow.

It is well understood that, in enlargement of the spleen associated with an excess of white corpuscles, it is desirable to resort to any method that offers a chance of reducing the size of the tumor. In doing this we aid in expelling the retained leucocytes and in directly stimulating its normal function. Gowers speaks of a case of splenic anæmia where no remedies improved the blood-stasis until the galvanic current was used. Under its influence the red corpuscles at once began to increase.[1] Botkin has spoken of the great therapeutic importance of electricity in splenic tumors. He considers the enlargement of the spleen to depend to a certain extent upon a diminution of its contractility, in consequence of which a retention of its contents takes place. Since the muscular fibres of the spleen can be excited to a greater activity by the electric current, we think that one of the injurious consequences of the swelling

[1] Ziemssen, vol. viii, p. 427.

of this organ may be diminished, *i.e.*, the increased stagnation of blood and the destruction of the red corpuscles. From his previous experience he thinks that these indications may be fulfilled by faradization of the spleen, not only in chronic but also in the acute splenic tumors of typhoid, recurrent, and intermittent fevers. Proceeding on these grounds he treated several cases of leukæmic tumors of the spleen involving the function of the liver, with benefit to both organs.

According to his statement applications of the induction current to the spleen caused the organ to grow smaller in all its dimensions, and with this diminution its consistency became tougher. After each electrization the number of red corpuscles increased, while the general condition, the appearance, and complexion of the patient decidedly improved. Simultaneously with the diminution of the splenic tumor under the action of the current, the liver clearly increased in size The latter diminished again as soon as the spleen began to increase in size, after the cessation of the electric current.

Although the continued faradization always produced a decrease in the volume of the spleen, as well as of the lymphatic glands, yet it clearly lost, little by little, in activity, for the most striking and beautiful results were always obtained in the first sitting. It is fair to say that Dr. Elias, of Breslau, who treated a leukæmic spleen in twelve sittings, according to Botkin's method, convinced himself that the apparent diminution of the spleen and enlargement of the liver depended only upon a strong contraction of the abdominal muscles, which pressed the still movable splenic tumor against the yielding diaphragm.

My experience in the electrical treatment of splenic disease associated with a congested and enlarged liver is limited to one case, in which electrical treatment proved to be of decided value :—

The patient was a man, aged 35 years, who while mining in the far West had been for a long time exposed to malarial influences. He had suffered from several severe attacks of intermittent fever, which greatly reduced his strength. When he came under my observation, both the spleen and liver were found to be distinctly enlarged. Anæmia was present to a marked degree, and, in addition to the very pronounced pallor which involved both skin and mucous membrane, the respiration was decidedly interfered with, especially when the recumbent position was assumed. I regarded the case as one of leucocythæmia, especially as, in addition to the characteristic symptoms above noted, there existed also a very decided hæmorrhagic tendency, which on several occasions had greatly reduced him. Unfortunately, no examination of the blood was made, and this robs the case of the interest of absolute certainty. General faradization was first attempted in this case, applications being made every day for a month, and especial attention was given to the localization of the current over the liver and spleen. Only a few applications were given before the patient observed some improvement in his general strength and the character of his respiration, but at the end of a month of treatment there was no observable diminution in the size of the enlarged organs. I then determined to supplement the more general method of treatment by the localized use of the static induction current of electricity, which, through its enormous tension, possesses great influence over muscular contractions. The patient was also treated by insulation and by sparks drawn from the affected sides, with the result of greatly accelerating the man's progress toward recovery. He improved in every respect, and after some two months of treatment he seemed to be almost as well as ever.

Cirrhosis of the Liver.—The most that can be said of electricity in the treatment of cirrhosis of the liver is that it will often relieve temporarily the pain that attends it, and in other ways modify the various associated symptoms. Atrophy of muscular and even nerve tissue we know to be amenable, in many instances, to the mechanical and nutritive effects of electrical applications ; but when the secreting cells of the liver atrophy, because of the compression due to excessive overgrowth of connective tissue, all efforts to stop the progress of the disease avail but little. If, however, the patient will abandon his habits of intemperance, if such exist, confine himself to an unstimulating diet, take exercise to the extent of his ability, and submit to proper electrical treatment, it has been demonstrated that life can be prolonged and rendered less burdensome. Among a number of cases of cirrhosis that have come under my observation, I can point to several that have been relieved of some of their symptoms by this method of treatment, and to one, especially, when life was undoubtedly prolonged for a considerable period. General faradization, daily employed, together with applications, to the point of endurance, directly through the diseased organ, not only in great measure relieved the dull pain in the neighborhood of the liver, but greatly lessened, and for several months kept in subjection, the ascites and œdematous condition of the legs that had for two months been prominent and distressing symptoms. These results seemed, in part, to be brought about by the action of the current upon the kidneys, which were excited to a greatly increased activity of excretion.

Jaundice.—In the consideration of this condition it should always be borne in mind that it is more a symptom of disease than the disease in itself. It results from various maladies, both curable and incurable, and, as a rule, our remedies should be directed toward the relief of the causative disease. The list of obstructive or mechanical causes of jaundice is a long one, and it would be futile, in the vast majority of cases, to expect any relief from electricity. It is entirely possible that, in cases of spasmodic stricture, or where the obstruction is due to gall-stones or inspissated bile, the galvanic and faradic currents respectively might, through sedative and mechanical effects, result in more or less benefit. It is, however, in some of the non-mechanical cases of jaundice that electricity exerts whatever beneficial influence it possesses in the relief of this condition. Of these non-mechanical causes of jaundice, there are two in which electricity may prove of direct and positive service : first, those cases where the normal metamorphosis of the bile is interfered with through deranged or impaired innervation ; second, where the same effect is produced through habitual and protracted constipation.

Several methods have been recommended to determine the differential diagnosis between jaundice due to obstruction of the bile-duct and those cases that are due to some one of the many non-mechanical causes, one of which is as to the presence or absence of bile-acids in the urine.

The test more generally accepted as reliable, however, refers to the presence or absence of bile in the stools. When the jaundice is due to non-mechanical causes, bile can, as a rule, be detected in the passages; while in the obstructive cases the stools have the characteristic light or clay color. In jaundice due to obstruction the discoloration occurs far more suddenly than when the cause is referable to interrupted metamorphosis of the bile.

To this there is one interesting exception, of which a number of examples have fallen under my personal observation. When the discoloration results from nervous causes, such as fright, grief, anger, or other emotional disturbances, it is apt to make its appearance quite as suddenly as when there exists actual obstruction of the bile-ducts. If, in case of obstruction by gall-stones, it is thought to make use of electricity, the faradic current is the form that should be selected, and simple local applications are all that are necessary. Currents of great strength can in this way be used, and, with the electrodes properly placed, it is entirely possible that muscular contractions of sufficient force might be produced to empty the distended duct. In cases of spasmodic stricture, localized applications of the galvanic current, of a strength up to easy endurance, might be tried. In regard to that class of cases brought about by various nervous causes, to which allusion has been made, a considerable experience teaches me that electricity may prove of the greatest service. In these cases there is almost invariably decided physical as well as mental depression. All the processes of secretion and excretion are liable to be sluggishly performed; and yet, associated with these functional derangements, there may exist very decided nervous irritability. In such cases, no merely local methods of application will serve our purpose; but, under thorough general faradization, I have, in many instances, witnessed changes for the better almost immediately.

With the patient stripped to the waist and with his feet upon a copper plate, connected preferably with the negative pole, the entire surface of the body should be subjected to the influence of the positive pole. Short applications are not, as a rule, satisfactory. If the patient is not unusually sensitive to the influence of the current, the applications should be continued for at least twenty minutes, and often for half or even three-fourths of an hour. I have in this way seen cases of jaundice of long continuance not due to obstruction, and the result of non-nervous as well as nervous causes, yield to this method of treatment in a comparatively short space of time.

Hydatid Tumors.—Since the experiments of Durham, Cooper, and Forster, at Guy's Hospital, London, many years ago, very few, if any, attempts have been made to follow up the suggestive results obtained at that time in the electrolytic treatment of hydatids of the liver. An old issue of the London *Lancet* (July 18, 1868) contains the following

description of a case of this character, which seems to me to be worthy of reproduction, in order to stimulate further investigation along this line :—

In one patient who was under the care of Dr. Hilton Fagge, and who was operated upon by Dr. Durham in June, 1868, the dullness in the hepatic region measured seven inches vertically, the ribs on that side were bulged, and the intercostal spaces prominent. Two needles were introduced into the most prominent part of the swelling, one piercing the space between the eighth and ninth costal cartilages, and the other about two inches behind it, between the ninth and tenth ribs. The needles were passed in to a depth of two or three inches. One of them was evidently free in fluid, for it could be moved about and rubbed against the other.

The posterior needle doubtless passed through the diaphragm, as it was jerked about by the respiratory movement. Both needles were connected with the negative pole of ten cells of the battery freshly charged. The positive pole, connected with a moistened conductor, was placed between and near the needles. The current was allowed to pass for twenty-five minutes, and during this time there was a crackling feeling under the finger, as of emphysema, owing to the development of hydrogen from the liquid of the cyst. After the operation there was some pain for four or five hours. In the evening the temperature was 100.9° F., and the patient did not sleep well that night. Next day the temperature was 99.6° F., and on the morning after it had risen to 101.2° F. At this time the hypochondriacal tumor had greatly disappeared, and the man expressed himself as feeling quite well. On examining the right side of the chest, however, Dr. Fagge was a little startled at finding absolute dullness up to the fourth or fifth dorsal vertebra ; and over this extent of the thorax there was loss of vocal vibration, marked tubular respiration and ægophonic character of the voice, which afforded conclusive evidence of a large effusion of fluid.

There was very slight pain about the points where the punctures had been made, but no pleuritic pain. The man lay on his back and felt quite comfortable. The liquid had evidently been squeezed through the puncture in the diaphragm into the pleural cavity. The man went on perfectly well, and the chest symptoms disappeared rapidly. Twenty days after all traces of the abdominal tumor had disappeared.

In addition to the foregoing, Mr. Durham claimed that eight other cases of a similar character had been treated successfully by the same method at Guy's Hospital.

Diabetes Mellitus.—As jaundice is not, strictly speaking, a disease of the liver, so diabetes is not strictly a disease of the kidney ; yet its predominating feature is such an overwhelming disturbance of the function of this organ that it has been considered desirable to treat of it in this connection. Moreover, the organic changes of the kidney that occur in the course of this disease are sometimes of the most pronounced character. Rokitansky, in his well-known series of necropsies, found that in the majority of cases there was well-marked disease present. Intense hyperæmia almost uniformly prevailed, and in some cases the organ was found to be much harder than usual, associated with vascular changes and diseased epithelium.

There are, however, strong grounds for believing that diabetes may be an essentially nervous disease. One is because of the well-established fact that injuries or diseases of the brain sometimes occasion this disease. More frequent causes of diabetes are emotional disturbances, —anxiety, grief, worry ; all and each, where prolonged and intense, may

directly act as exciting causes. Another argument in favor of the nervous origin of the disease is the fact that in not a few instances remedies directed alone to the central nervous system have very favorably influenced its course.

Both sugar and glycogen—a substance very nearly allied to sugar—are found and formed in the human body when in its normal condition, but it never appears to any extent in the urine of a person in health. As it is not found, to any appreciable extent, in the other excretions of the body, it is evident that it must be used up or transformed in the circulation; but where, or how, oxidation occurs has not been quite determined. The system may suffer from an excessive accumulation of sugar either through quantity from without, greater than can be destroyed by the normal processes, or through some impaired nerve-influence that interferes with the complete and necessary oxidation of sugar.

The kidney is the one easy, natural outlet through which the sugar is excreted when circulating in the blood in excess; and, although it is usually associated with an excessive flow of urine, yet this is not necessarily the case. It is not at all uncommon to find a considerable deposit of sugar, and yet no marked increase in the amount of urine discharged; and from this we conclude that neither this increased formation of sugar nor the diminished capacity for oxidation has a necessary connection with the abnormal urinary discharge that is such a constant symptom. Our knowledge of the etiology of this disease is most unsatisfactory, but experience teaches that there are two exciting causes that are not infrequent.

The first of these is disease or injuries of the brain, and the second is mental strain. Whether this manifests itself in the form of long-continued anxiety, profound and lasting grief, or seasons of prolonged excitement, emotional disturbances are potent factors in the production of diabetes. The late civil war illustrated the potency of intense nervous excitement combined, perhaps, with exposure and errors in diet in inducing this disease. I readily recall, at this late date, cases of diabetes that occurred during and after the close of the war that were undoubtedly due to these causes. Abnormalities in the functional activity both of the liver and kidney must often depend on causes that are very similar. The sympathetic seems to exercise a controlling influence over both.

In the former its special fibres descend from the medulla, leaving the cord at its lower cervical or upper dorsal vertebræ, finally reaching the liver. In the latter these special fibres leave the spinal cord farther down in its course, joining the great abdominal plexus before it reaches the kidney. Exploration of the sympathetic nervous system has not, however, been able to detect any lesion which would directly associate it with the disease in question. The fact that extravasations of blood in cases of diabetes have been found in various portions of the central

nervous system has given rise to the theory that it originates in lesions of the nervous system represented by enlarged perivascular spaces, the sites of existent or pre-existent extravasation of blood, with destruction of the surrounding nerve-tissue. This theory is not, however, believed to be tenable. The characteristic chemical features of diabetes are sufficiently familiar, and the tendency is for them to progress steadily to the end. And yet not a few cases, if judiciously managed, not only very much improve in all their symptoms, but in some cases perfect recovery has been known to take place. In a considerable number of diabetic cases that have fallen under my observation, I cannot, indeed, refer to any that have completely recovered, or who have been so permanently improved in all their symptoms that no relapse ever occurred. In common with others, however, who have had experience in the management of diabetes, I have seen very considerable improvement in all the symptoms follow known and accepted methods of treatment, hygienic and otherwise. It is, moreover, my opinion, based upon some considerable experience, that if, in addition to dietetic, hygienic, and medicinal treatment, we include electricity, results will be obtained, in a certain proportion of cases, that would be impossible without it. Both galvanization of the brain, preferably by the method of central galvanization and general faradization, are the methods that have, in my hands, sometimes aided in unmistakably modifying the severity of the symptoms for which relief is sought. I fully appreciate the fact that it is exceedingly difficult, if not impossible, to determine the exact measure of benefit derived from any special method of treatment when it is only one of a number of others that are simultaneously in use.

It has been my aim, therefore, in the treatment of many different conditions, and so far as it could be done without sacrificing the best interests of the patient, to test both the relative and absolute therapeutic value of electricity; and in a case that Dr. Chas. A. Dana once saw with me, in consultation, I was enabled to very distinctly determine the benefit that electricity was capable of giving.

The patient, a lady somewhat beyond middle life, was suffering not only from diabetes, but also from locomotor ataxia. In regard to the latter disease I was at first in some doubt as to whether it was a case of actual sclerosis of the cord or one of those cases of which I had met a number, where the symptoms very closely simulated true locomotor ataxia, but without structural disease of the cord. A careful and prolonged examination convinced us both that the disease was organic, and not functional. There was the characteristic inco-ordination of movement, cutaneous anæsthesia of the fingers and toes, sudden and shifting pains, and the absence of the patellar reflex. The patient was quite helpless, and could walk only with assistance. The flow of urine was not excessive, although decidedly greater than normal, but sugar was found in large quantities, and on many different occasions.

This patient was under my observation for many months, and I had abundant opportunity to test and contrast varied methods of treatment. She improved greatly in her locomotion, so that she was enabled to walk easily without assistance, and this improvement I attributed in great measure to the adoption of the suspension treatment to which

she was persistently subjected. Under diet, hygienic methods, internal medication, especially the bromide of arsenic and electricity, the urine cleared up in great measure, and for a long time showed absolutely no evidences of sugar. Now, the reason why I believed that electricity greatly aided in affording relief to this patient was this :—

She came to me in October, 1890, and was immediately put upon strict diet, medication, and electricity. Within a month she had decidedly improved. She walked better, slept better, had less anæsthesia and pain, while the flow of urine and amount of sugar found had very greatly decreased. I now suspended altogether the electrical treatment, and for about a month continued as before with the other methods. The patient not only failed to improve further, but became decidedly worse in every symptom referable to her diabetic condition. She began to pass urine more freely, and an examination showed a decided increase in the amount of sugar discharged. Her sleep became more disturbed, and a certain itchy and eruptive condition of the skin, from which she had previously suffered, but which had entirely disappeared under treatment, returned in full force.

Again the electrical treatment was resorted to, and again improvement manifested itself in short order. The itching ceased immediately and normal sleep was restored at once, but it was not until after several urinary analyses that the amount of sugar was found to have sensibly decreased. On one other occasion during the treatment, which lasted through the entire winter, the electricity was again intermitted for a few days, with the result of some return of the itching and a slight skin eruption. Never after this, while under treatment, would the patient consent to any cessation of the electrical applications. After this patient left for her home in another State, she retained for months the improvement that resulted from the varied treatment administered, but subsequently she was seized with an attack of *la grippe*, from the effects of which she succumbed.

The electrical treatment that I administered in this case was general faradization, alternated with central galvanization. General faradization I administered thoroughly, from the head to the feet, and with a strength of current up to the point of easy endurance. By using electrodes of large size, and accurately adjusted to the surface of the head, I was enabled to use currents as high as 20 milliampères in strength. More than this occasioned pain, and once she complained of sudden nausea when the strength had been raised to 28 milliampères.

There was not in this case, to my mind, the slightest doubt but that electricity had been a most important aid in the relief of the symptoms so happily obtained. It would have been both interesting and valuable to have tested the comparative value of the two methods—central galvanization and general faradization—in the treatment of this case, and I regret that this was not done. I believe, however, that both methods were of value, the action of the galvanic current on the central nervous system supplementing the mechanical and tonic influence of general faradization on the system at large. It is well understood how exceedingly important well-regulated physical exercise is to the diabetic, but this patient, on account of her other infirmity, was unable to walk to any sufficient extent, and, for pecuniary reasons, was unable to ride regularly. General faradization acted as a substitute for these. It gave passive exercise to all the deeper-lying as well as superficial tissues, and, through the contractions it excited in both voluntary and involuntary muscles, raised the temperature and increased the process of oxidation.

Polyuria.—For the sake of convenience only do we include polyuria,

or diabetes insipidus, under the head of diseases of the kidney, since, strictly speaking, it is no more a disease of this organ than is diabetes mellitus. As a rule, post-mortem examinations reveal no changes in the organ excepting increased vascularity, although in some cases that have been exceptionally chronic in their course structural changes have been observed. It seems reasonably evident, from the results of direct experiment, that polyuria, with its various subdivisions, should be classed among the neuroses. Bernard found that copious diuresis could be induced in animals by irritating certain portions of the floor of the fourth ventricle, and injuries to the central lobe of the cerebellum cause the same result. The splanchnics and spinal cord are regarded as the paths along which influences originating in the fourth ventricle and central lobe are transmitted to the kidneys, but it has not been determined "whether the nerves are merely vasomotor fibres, section or paralysis of which would produce turgescence of the vessels of the kidneys, or trophic fibres, irritation of which would increase the activity of these organs; but, in all probability, paralysis of the vasomotor fibres is the main factor in the production of hydruria." This reasonable theory of the etiology of the disease strongly suggested the possibility that electricity would prove of value in its treatment; but while it cannot truly be said that it is altogether useless, yet, speaking personally, experience in the treatment of many cases has not confirmed the brilliancy of its promise.

To arrive at correct conclusions as regards the efficacy of electricity or any other method of treatment in polyuria we must be sure of our diagnosis, and I am impelled to lay especial stress upon this point because it is not very unusual for an excessive and more or less prolonged discharge of urine having a low specific gravity to be mistaken for polyuria. In hysteria and kindred conditions the flow of urine is often excessive, although the special nervous symptoms associated with them render the differential diagnosis not very difficult. Disorders of the metabolic function of the liver are also not infrequently accompanied by a free and prolonged discharge of urine, which has resulted in errors of diagnosis.

If, as is usually the case, it is impossible to assign a special cause in the production of polyuria, our efforts must be in the direction of supporting the general health, so as to counterbalance so far as possible the enormous drain upon the system. In connection with a nourishing diet and tonics of strychnine and iron the general application of the faradic current and the galvanic current, used centrally and locally, are useful methods. In some instances polyuria has decided nervous affinities, and in these cases electricity performs a special function. I have known it to relieve nervousness bordering on hysteria in a case of polyuria that had resisted valerian and other antispasmodic remedies, and to finally aid, if it was not the main factor, in the recovery of a persistent

case of this character. Notwithstanding, however, the occasional good results that follow this and other methods, the treatment of polyuria is, in general, by no means satisfactory.

Hyperæmia of the Kidney.—The writer once reported a case of Bright's disease the symptoms of which rapidly improved under electrical treatment until, finally, recovery took place. In support of the diagnosis of Bright's disease both albumen and hyaline tube-casts were found, together with a diminished quantity of urine, but subsequent experience in the treatment of the disease failed to justify the expectations raised by this one case. Evidently the diagnosis had been erroneous, and, looking back from the stand-point of a considerable experience with cases somewhat similar, I am of the opinion that the condition supposed to be Bright's disease was simply one of hyperæmia. While such mistakes in diagnosis ought not, perhaps, to be made, yet it is not remarkable that the two diseases should occasionally be confounded.

Hyperæmia of the kidney, active or passive, like the more serious disease for which it is sometimes mistaken, is characterized by the appearance of albumen in the urine and, more rarely, by the presence of hyaline casts in very small quantity. The diagnostic points between hyperæmia of the kidney and Bright's disease are, therefore, not always clear at first sight. In hyperæmia, to be sure, the urine is almost invariably small in quantity, but in Bright's disease this is also often the case. A generally distinctive feature lies in the fact that in congestive conditions the urine easily deposits blood, renal epithelium, or tube-casts, is high-colored, and of natural specific gravity. Active congestion of the kidney is best treated by the ordinary method of dry cupping, warm baths, etc., while any inducing cause, such as heart disease or pulmonary disease, should receive their appropriate treatment. Active hyperæmia, as a rule, rapidly subsides, but the passive form is more persistent and tends to recur. General faradization, properly and persistently applied, is a remedy of no little value in the treatment of this condition, and under its use it is not uncommon to witness not only temporary relief of pain and an increase in the flow of urine, but permanently curative effects.

GOUT AND RHEUMATISM.

Gout.—Gout is a disease which, in the majority of instances, is so thoroughly dependent upon errors of food, drink, exercise, and the influences of heredity that its prevention and cure depend for the most part on the observances of strict hygienic methods rather than upon drugs or electricity.

It is within the experience of every physician that hereditary influences are alone sufficient in many cases to occasion attacks of gout. The

victim may be most abstemious in all his habits of eating and drinking and active in exercise, and yet suffer at intervals from the characteristic pain and swelling of the smaller joints, clearly indicating the lithic-acid diathesis. I have seen several cases of this character in which the loss of nervous tone was such a prominent feature that the term "nervous gout" seemed entirely applicable. Electricity serves a useful purpose in such conditions. It is distinctly palliative, and a certain proportion of cases react to its effects in a most gratifying manner.

There is one phase of the subject to which more consideration should be given, in the study of electricity in its relation to disease, and that is the remarkable variation in the susceptibility of different individuals to its effects. One can appreciate fully the fact, however, only after long and varied experience. To say that some persons were not born to be treated by electricity is a strong expression, but thoroughly true. The observation was made years ago, and proofs of its substantial accuracy accumulate year by year, without regard to the nature of the symptoms or the disease. There are, on the contrary, those whose tendencies and susceptibilities are quite in the opposite direction, and who respond most kindly to any form of judicious electrical treatment. One of the most interesting evidences of the truth of this statement occurred in the person of a patient who first consulted me nearly ten years ago, and who, for many years subsequently, I was enabled to keep under a general observation.

When I first saw him he was a young man, aged 26 years, and at that time was suffering from a distinct gouty swelling of the metatarso-phalangeal articulation of the great toe and a large joint of the index finger.

He gave a history of direct hereditary transmission through several generations, and, although both his father and grandfather had been high livers and indulged in the free use of wines, he himself had been from childhood unusually abstemious in eating, had never touched liquor of any kind, and was an enthusiast along the line of athletic sports. He belonged, however, to the true neurasthenic type that is now so familiar to every observing physician, whether a specialist in neurology or not. This was by no means his first attack. They came on at irregular intervals, sometimes one or two years intervening between the paroxysms, and then again only a few months. On each occasion the joints were exceedingly stiff, swollen, and painful, invariably keeping him from all active exercise for a month or six weeks. The results that followed the use of electricity on many different occasions in his case conclusively proved that he was one of those "born to be treated by electricity."

General faradization was always followed by a very marked alleviation of pain and invariably shortened the attack. Repeatedly resorted to in various subsequent attacks, it has always proved immediately palliative, and has, in my opinion as well as that of the patient, permanently reduced their severity, as well as frequency. Acute attacks of gout, however, depending upon errors of food and drink, combined with indolent habits, offer no special field for the beneficial effects of electricity. It is, indeed, doubtful whether it would prove of the slightest service in those every-day cases of gout that are so familiar.

Taking into consideration the catalytic and absorptive power of the galvanic current, it has been believed that much could be accomplished through its use in dissipating the gouty concretions that form in the various parts of the body. Experience has, however, not been very satisfactory in this direction.

The deposits of urate of soda resist with great persistency all external and mechanical methods, and the few reports of success in these attempts have not been satisfactorily confirmed by wider experimentation.

I have in past years treated many cases of this character, but I am bound to say that I have never yet seen a true calcareous deposit in the joints diminished in any appreciable degree by any form of electrical treatment. I have, however, known of actual damage being inflicted by a too confident and careless resort to the galvanic current. In December, 1891, a gentleman called upon me, inquiring if electricity could do anything to relieve his hands and feet, stiff and crippled from repeated attacks of gout. That the urates had been deposited in large quantities was evidenced by the great deformity and unusual size of many of the joints, and especially those of the hands. The skin, as it stretched over the concretions, presented the characteristic bloodless and shining appearance, and looked as if, under provocation, it might readily give way. I told him that electricity could do nothing for him. Within a week he returned, saying that he had been assured by another that the galvanic current would certainly help him, and upon this assurance he submitted to two local applications of the current, strong enough to occasion sharp burning and to redden the skin. The almost immediate result was an excoriation, which is likely to be permanent.

There is much truth in the statement that "he only has gout who will have it." Leaving heredity out of consideration, it is an easily preventable condition, and is brought about in the majority of cases by grossly unhygienic methods of living. Its prevention and cure, therefore, depend for the most part on a return to proper methods of living, both as regards eating and drinking and exercise, and only in so far as electricity can be made to produce effects similar in kind to that obtained through muscular exercise is it of any therapeutic value. In those cases, therefore, where from any cause adequate active exercise is not practicable the mechanical effects of the faradic current, after the method of general faradization, is certainly indicated, and its tendency is to do good.

Rheumatism.—There is perhaps no one disease for which electricity has been more frequently attempted, nor one in which its virtues have been more extravagantly proclaimed, than rheumatism. I may also add that, among those diseases in which electricity possesses a well-recognized and very positive value, there are few where it more frequently yields disappointing results than in this condition. The reason for this lies in

the fact that a proper discrimination does not enter into the selection of cases.

Before electricity became legitimatized, as it were, in the profession its charlatan element in some cases gained great *éclat* among the laity for their unusual success in treating rheumatism by electricity. Every muscular pain was termed rheumatism, and in those cases of the true muscular variety of the disease, so many of which recover spontaneously in a few days, the remedy seemed to the uninstructed mind quite magical in its effects. In acute articular rheumatism electricity in any form is of doubtful value. In any event, it is very difficult to make satisfactory applications to the inflamed joints and sensitive muscles. It is an acute febrile disease, characterized by profound constitutional disturbance, while its pathology is admittedly obscure.

Whether we accept the lactic-acid theory—the germ or the infective theory—or the malarial theory, it is probable that organic poisons, introduced from without or produced within, are the important causative factors of the disease, in its acute form especially. While general and local palliative treatment may give great comfort to the patient, and occasionally may prevent complications, it is yet doubtful whether an attack of acute rheumatism can be very much shortened by any method of treatment. I have, however, seen unmistakable evidence of the benefit to be derived from the use of electricity after the decline of the acute symptoms and the disappearance of the enlargements and excessive tenderness of the joints. In my own experience this point has been satisfactorily determined, by observation in cases when in repeated previous attacks convalescence was more prolonged than after resort was had to treatment, by the method of general faradization.

Subacute articular rheumatism is far more favorably affected by electrical methods of treatment than the acute form; but, even in these cases, it must be admitted that the remedy acts with a degree of capriciousness that is often very discouraging. There are some cases that will not be benefited at all by electricity. I have known a number of cases in which increased pain, heat, and redness were occasioned by any and every attempt in the use of this agent.

These unsatisfactory results must be attributed not so much to the disease itself as to the peculiar individual idiosyncrasies that occasionally assert themselves so vigorously under electrical treatment. There exists a class of cases of the subacute variety of rheumatism which has served an excellent purpose in fostering the credulity of those who make of electricity almost a panacea in the treatment of rheumatic conditions. Under any circumstances, either with or without treatment, the duration of these cases is exceedingly short, in many instances not exceeding two or three days. Now, in an attack of this kind, if one is so fortunate as to see the case *ab initio* and electricity is employed, to electricity is given the entire credit of the cure. I well remember a perfectly

honest but ignorant so-called electrician, into the mysteries of whose practice I gained some insight, a number of years ago. He believed electricity to be an unfailing remedy in rheumatism, and this belief was shared by a multitude of people influenced by his success in these transient, subacute cases of rheumatism, which came to him in large numbers, and as soon as the first symptoms of pain manifested themselves.

But there is another not infrequent group of rheumatic cases of the subacute variety in which electricity serves a most excellent purpose, allaying irritability, lessening the heat and pain in the joints, and appreciably shortening the duration of the attacks. It does more than this. From a considerable experience, I can confidently assert that by its use the severity of subsequent attacks will be greatly lessened if the tendency to recurrent paroxysms is not entirely destroyed. I am well aware that these cases of subacute rheumatism, occurring in persons approaching middle life or beyond it, tend, in subsequent attacks, to lessen the severity, sometimes; but careful observation in many cases enables one to discriminate between what is and what is not the result of the treatment administered. According to my own experience, there is only one satisfactory method of electrical treatment in these cases, and that is the method of general faradization with the descending current. Purely local applications, while, perhaps, not altogether useless, are by no means so efficient as the general method. I have, time and time again, because of the labor entailed and the objections of patients to disrobing, confined my efforts to applications to the joints alone, but always with results unsatisfactory when compared with the general method of treatment.

Muscular rheumatism is also, in many cases, obedient to some form of electricity in a very marked degree. We have here a condition affecting mainly the fibro-muscular structures, associated with pain and sometimes spasms of the affected part. The exciting cause is most frequently exposure to draughts, and such exposure is especially apt to be followed by severe and persistent attacks if, associated with it, there has been any strain of the fibro-muscular structure. It is unnecessary to enter into any detailed description of the symptoms of muscular rheumatism.

As a rule, although not in every case, rest greatly alleviates the pain, while movement of the affected muscles is attended by sudden spasmodic pain of an excruciating character. It hangs on, with varying degrees of persistency, from a few days to weeks and months, and, in some of the more severe cases involving the fibro-muscular structures, it has been known to occasion years of suffering. All three forms of electricity—galvanic, faradic, and static—are of value in the treatment of muscular rheumatism; but, taking the cases as we find them, I myself have not only found static electricity to be the most efficacious

of all the electrical methods, but, among those who have experience with the three forms in the treatment of the disease, the same judgment, I find, prevails.

If a case of muscular rheumatism came to me in which the pain was of a neuralgic type, and with considerable tenderness to pressure, especially slight pressure, I should choose either the galvanic or the faradic current of high tension, preferably the former. In a certain proportion of such cases it will be found that the treatment will almost immediately dissipate the tenderness and lessen the pain, as well as hasten recovery; while static electricity will, as a rule, afford no relief, but may even aggravate the pain. An exception must, however, be made in favor of the static induction current, which, with its infinitely rapid succession of sparks, becomes dynamic in character, and allied, in its effects, to the faradic current of high tension. If, however, the opposite condition of things prevail, as is more frequently the case in chronic cases of muscular rheumatism, static electricity is capable of far greater relief than either of the other two forms. In these chronic cases there is often but little pain on pressure; indeed, pressure often affords relief. The pain is dull and aching, and seemingly very deep-seated, even when in repose. I have, in fact, seen many cases when the pain became entirely subdued during more or less vigorous and protracted exercise, the excitation of the circulation and the heightened activity of the various excretory and secretory processes of the body seeming, for the time being, to take away every reminder of the disease. The method to be adopted is the simple one of insulation and submitting the patient to the effects of the roller electrode over the affected parts. It is by no means a pleasant method of procedure, but, if continued for twenty minutes or half an hour, it is quite remarkable the relief that is afforded. Sometimes, but not generally, this relief remains permanent after a single application. I have known of cases of lumbago, after suffering for weeks, to be completely and permanently relieved after a single *séance* of this kind.

Rheumatoid Arthritis.—There is one other manifestation of the rheumatic diathesis which should be referred to in this connection, notwithstanding the generally unfavorable prognosis attending its treatment.

Reference is made to rheumatoid arthritis, a chronic inflammatory condition of the joints associated with degenerative changes and resulting in various degrees of deformity. Almost every joint of the body may become affected, and it is usually observed that in the joints of the extremities, especially those of the knee, elbow, wrist, and fingers, the effusion is greater and the deformity more pronounced than elsewhere.

In quite a large proportion of cases the sufferers from rheumatic arthritis give a history of acute articular rheumatism, or at least of a

mild form of chronic articular rheumatism, although in other cases no such history is given.

Where there has been no previous rheumatic symptoms it will often be found that the predisposing causes have been depressing influences of some kind,—such, for example, as are associated with or follow frequent pregnancy, excessive lactation, any form of acute disease, or prolonged and exhaustive efforts, mental or physical. It must not be forgotten, however, that in many cases the disease is distinctly hereditary, and the slightest injury to a joint in a person apparently in perfect health has been known to be a sufficient exciting cause. When we consider the pathology and anatomical characteristics of rheumatic arthritis, the persistency with which it fails to respond to the most varied treatment, both constitutional and local, is readily appreciated. As the disease progresses the effusion greatly diminishes; but the intra-articular structures are in many cases irreparably damaged. The fibro-cartilages, ligaments, and tendons disappear, and the opposed surfaces of the articular cartilages become ossified and irregular in shape. Even the shafts of the bones become affected, increasing in size and altered in shape and density, and both ligaments and muscles suffer atrophy and displacement.

While these are only a few of the structural changes that might be enumerated in this connection, they sufficiently indicate the unpromising nature of the disease; and, excepting in rare instances, it is doubtful whether it can be cured or the morbid process arrested.

There are, however, certain local symptoms, of a very distressing character, that can be relieved by various methods of treatment, among which electricity holds not the least important place. The pain and tenderness is often of the most excruciating character, and so continuous as to prevent sleep and render life altogether miserable.

I have found electricity to be palliative in a marked degree, in not a few of these cases, not only in the way of relieving pain, but in increasing mobility.

On theoretical grounds, one might, perhaps, prefer the galvanic current in the treatment of this condition, but my own experience with a considerable number of cases is altogether in favor of the faradic current, and the higher its tension the greater appears to be its analgesic properties. For this reason, the static induction current, the tension of which is enormous, is often serviceable.

In one case of rheumatoid arthritis that I recall, the disease affected not only the extremities, but had extended to the sterno-clavicular articulation and to the spine. The pain down both arms was very severe, and as the disease progressed the patient found it more and more difficult to walk in an erect position or to bend over without occasioning severe pain in the spine.

Frequent and long-continued applications of both the faradic and

static induced currents of electricity were followed by the most marked and grateful relief in this case, and not only as regards pain, but in the ability to assume and retain a more erect posture.

In consideration of the treatment of the chronic articular and muscular forms of rheumatism, the application of the faradic brush should be mentioned. A vigorous current, sufficient to produce intense redness of the skin, is sometimes followed by great relief.

ELECTRO-THERAPEUTICS OF DISEASES OF THE LUNGS AND HEART.

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The physiological effect of electricity upon respiration and the heart's action has been comparatively little studied, especially its application through the skin. That it has some effect upon the heart, circulation, and movements of the diaphragm is well demonstrated by its therapeutic action in certain diseases. Coughing can be provoked by passing a galvanic current from the cathode at the nape of the neck to the anode on the dorsal vertebræ and breaking or reversing the current. By this procedure tickling in the throat is excited and coughing.

A galvanic current applied directly to the ganglion of the sympathetic causes dilatation of the pupil, contraction of the blood-vessels of the eye, ear, and cheek, and lowering of the temperature (0.5° to 1.75° C.) upon that side. When the current is applied to the skin behind the angle of the jaw these results are not obtained, or not with certainty. Contraction of the pupil, under these conditions, has been reported by some observers and dilatation by others; and by most no change has been noticed. A lowering of blood-pressure and lessening of pulse-rate have also been claimed as a physiological effect, but these observations are not confirmed. Somnolence, vertigo, increased temperature, and sweating of the hand on the side galvanized are other uncertain effects observed in healthy persons. The therapeutic effects obtained from currents applied to the neck in the neighborhood of the sympathetic are thought by G. Fischer to be due to excitation of the pneumogastric and of the cutaneous nerves. The pneumogastric can be galvanized by applying one electrode along the external border of the sterno-cleido-mastoid, a little below its middle, and the other over the heart. In this way a rapid heart can be slowed with much uniformity. The excitation of the pneumogastric calls forth more powerfully its inhibitory action upon the heart. The faradic current has been applied to the same point on the neck and over the cartilage of the seventh rib, or to other points where the diaphragm is inserted into the thorax, with success in order to stimulate a paralyzed diaphragm to act.

Von Ziemssen has studied the action of currents passed through the body in the cardiac region. His observations were made upon one whose heart was covered only by skin, the sternum and ribs having been removed. He found that when strong galvanic currents were passed through the heart, one electrode being placed upon the præcordia and

the other directly opposite on the back, the heart could be made to beat more rapidly by steadily breaking and making the current a little oftener than the heart was beating. The heart quickened until it beat in unison with the breaks in the electrical current. The heart could not, however, be made to slacken its rate with equal certainty. A repetition of these experiments, by many observers, upon persons whose thorax was uninjured, and who were in a state of health, has been fruitless,—perhaps because the currents used were too weak. I do not learn that this method has been tried when the heart was in a pathological state, persistently beating too fast or irregularly.

Faradization of the muscles of the chest in *consumption* was advocated by Bartings as a form of gymnastics which led to hypertrophy of the muscles of the thorax, and therefore to deeper and stronger breathing. He claimed that this affected, or at least contributed, to a cure of phthisis. Bartings claimed cures even after excavation had begun in the lungs. It has been shown by others that the size and strength of the chest-muscles can be improved in this way. But such muscular hypertrophy can be regarded only as one factor of many necessary to the cure of consumption. The mode of treatment has gone completely out of use. Haynes has claimed good results in the same disease from the use of the galvanic current when one electrode was placed behind the angle of the jaw and the other over the pneumogastric nerve. He claims that the lungs dilate more fully and that the respiratory movements increase. Though favorable general effects are noted by him as following this treatment, it is doubtful if they were more than accidental, and we are not told that they were more than temporary.

A constant current has been used when there was an *effusion into the pleural cavity* by placing the poles at somewhat distant points on the thorax, over the accumulated fluid. After such treatment the amount of serum in the cavity diminished, but this often happens when electricity is not employed, and I do not think that we are justified in placing reliance upon such treatment until a larger number of trials of it are reported than have as yet been found by me. Both the faradic and galvanic currents have been applied in various ways to the chest distended by *emphysema.* Sometimes no effects were noticed; rarely, various and at times contradictory ones were observed. From our present knowledge it seems, in this disease, also useless to employ electricity.

In the following diseases electricity has a more positive value as a therapeutic agent. Therefore they are described with more detail. Brief mention is made of other therapeutic agents that can be used with advantage simultaneously, or instead of the galvanic or faradic currents.

Asphyxia.—Asphyxia has been treated by electricity usually without success, but with some brilliant results. It is applicable to all cases in which there is a chance of restoring respiration by maintaining artificial respiration. The faradic current should be used, and should be

applied by large sponge-electrodes to the phrenic and along the insertion of the diaphragm into the thorax-wall. The current first used should be strong enough to contract the muscles of the thumb vigorously. The current should be interrupted as often as three times a minute. If necessary, the current can gradually be made stronger. If the faradic does not produce good results, the galvanic current can be tried, though it is less frequently successful in re-establishing respiration. It should be used as it has been advised for paralysis of the diaphragm. (See page 7.) Before electricity is applied, the shoulders and arms should be held firmly. Regularly intermitting pressure upon the abdomen should also be made to help provoke movements of the diaphragm. Dry electrodes were used by Lauth. Jacobi believes it matters little where the electrodes are placed,—upon the chest or neck,—at least, when applied to newborn infants. He explains the results obtained by the faradic current as due to the pain which it causes. At first he found feeble respirations made deeper and more frequent, and the heart quickened and strengthened; but if the current was administered more than a few minutes at a time, it became slower, and the child would appear fainting. Therefore it is essential, and especially if dry electrodes are used, that the current should be interrupted every few minutes. This method of provoking respiration has been tried successfully upon newborn infants in whom breathing did not begin spontaneously. It is also applicable to chloroform, opium, and other drug narcosis, and to drowning. It is only a moderately successful mode of treatment, but, when the electrical instruments are at hand, it should be tried with others, though it ought not to be used as a complete substitute for them. A powerful current ought not to be used at first, for in at least one case, described in Baird & Rockwell's "Electro-Therapeutics," the heart stopped beating as soon as the current was applied. It can be conceived that a strong current might stop the heart when it was beating feebly.

Asthma.—Asthma is an expiratory dyspnœa, which occurs paroxysmally, and is usually sudden in its onset. As a rule, the paroxysms are, at longest, of only a few hours' duration. The exact nature of these attacks is unknown. They are generally believed to be due to spasmodic contraction of the bronchi, which is excited through the agency of the nervous system. By some it is believed that the bronchi are narrowed by sudden and very great congestion of their mucous membranes, produced through the active agency of the vasomotor nervous system. The trachea and that part of the right bronchus which can be seen in a laryngeal mirror are observed to be congested during an attack of asthma. A few persons think the dyspnœa is due to a spasm of the diaphragm, which causes an enlargement of the thorax, and, therefore, sudden dilatation of the lungs, difficult and unnatural respiration. It is true that in many cases of asthma movements of the diaphragm cannot be demonstrated, but in others they can be. Therefore the explanation is not of

universal applicability. Most, if not all, cases of asthma are of reflex origin.

Asthmatic attacks usually occur in periods lasting from a few days to several weeks, during which they recur at regular, and usually at daily, intervals. The periods may be weeks or months apart. Less frequently a single paroxysm of dyspnœa will occur not followed by others, or followed by them only after a long intermission. In the majority of cases there are no premonitory symptoms, but in a few of them they occur, and are peculiar to each individual: for instance, in one person attacks are uniformly preceded by an unnatural drowsiness, or by sneezing, itching, flatulence; by the passage of large quantities of very pale urine; or by various other symptoms, which the sufferer's experience leads him to recognize as warnings of an approaching attack.

The dyspnœic paroxysm usually occurs in the earliest morning hours, in a majority of cases between 2 and 4 o'clock. The sufferer generally awakes from a sound sleep with oppression of breathing. The dyspnœa becomes intense almost at once. A patient may seek relief at an open window, or assume some favorite attitude which he has learned makes it possible for him to breathe with the most ease. These attitudes are various: one may sit upon the edge of the bed or upon a chair, the side of which is grasped by the straightened arms, and the shoulders thus made rigid. The body is bent a little forward, the head is thrown back, and the mouth is opened to permit the freest ventilation of the lungs. At first the countenance expresses anxiety, and later extreme distress, as the symptoms of suffocation intensify. A warm, moist perspiration starts out over the upper part of the body and face at first; but if the dyspnœa is prolonged and intensified, the skin becomes cool, clammy, in color often ashen, and lips and finger-nails purplish. Thus, cyanosis is developed. The pulse is quick, frequently irregular, small, and rigid. The veins of the neck are unusually full. The bodily temperature is rarely abnormal.

A physical examination shows that the respiratory movements are no more, or very little more, rapid than normal. The thorax is dilated. The intercostal spaces are persistently stretched to their widest extent. The ribs do not move freely on their axes with each respiration. As the chest is thus constantly extended to its utmost, inspiration is only effected by lifting the thorax as a whole by the unusual muscles of respiration. The inspiratory act is short and jerky and the expiratory is prolonged and labored. In children the lower part of the chest will be observed, during inspiration, not to expand, but to be retracted. In adults this appearance is little noticed, as their ribs are too rigid to be thus bent, but the lower intercostal spaces, and often the supra-clavicular spaces, are retracted. Palpation usually reveals no change. Percussion reveals an increased resonance, uniform upon both sides of the chest. The area of resonance is also increased; therefore the area of dullness

over the heart is diminished, and the area of liver dullness is depressed and seen to change less in its horizon with inspiration and expiration than natural. The apex-beat of the heart can frequently not be seen or felt, and its sounds are somewhat distant because of the overlapping lung. Auscultation is not necessary in order to hear the abnormal respiratory sounds, for they are so loud that they are audible many feet from the sufferer. If the ear is placed on the chest, vesicular sounds will be found entirely absent, and only piping and crowing will be heard. The inspiratory sound is very short, the expiratory much prolonged.

Usually when the dyspnœa is most intense, the cyanosis most marked, and fatal suffocation apparently imminent, relief comes and the oppression rapidly abates. With or very shortly preceding this abatement a slight cough begins; it may be so slight as to be unnoticed. Usually it is accompanied by the expectoration of a small number of sputa-chunks, of small size and glairy, gray, adhesive character. If the sputa is examined microscopically, it is often found to contain characteristic elements, such as spiral coils of thread-like fibrils and the needle-like crystals of Charcot. The cellular elements are those usual to sputa.

Such a paroxysm as I have described typifies the severest type of the disease. Every grade of milder form can be observed, to that in which there is only a feeling of respiratory oppression. The duration of the paroxysms of dyspnœa is variable. It may be a few minutes or one to three hours. In rarer cases it will be several days. Intervals between attacks of asthma are passed in perfect comfort. When the dyspnœa first ceases, exhaustion is often so great that a quiet and sometimes protracted sleep sets in. On awakening, the patient usually feels perfectly comfortable, and at this time an examination reveals no abnormal physical signs.

In treating asthma its causes should be removed if possible. They are both predisposing and exciting. In some cases the cause is unknown, and such are often described as idiopathic. The disease occurs most frequently between the ages of twenty and forty, and oftener in males than in females. Most asthmatics are nervous by temperament. It is regarded as inheritable, because it often attacks some members of several generations of the same family. Scrofula, heart diseases, Bright's diseases, gout, and rheumatism are very frequently associated with asthma, and are regarded as predisposing to it. The exciting causes are numerous, and vary with the source of irritation, whence reflexly the bronchial spasm is produced. The commonest sources of irritation are in the nose, bronchi, pharynx, stomach, and womb.

If acute and chronic nasal catarrh or nasal polypi are the causes, they should be cured or removed. Asthma very frequently occurs with the coryza of hay and rose fever, which is generally supposed to be produced by a vegetable dust peculiarly irritating to certain individuals. Bronchitis is often accompanied by asthma. Less frequently enlarged

tonsils and pharyngeal and laryngeal growths are the source of irritation of the disease. Irritation of the stomach very rarely is the exciting cause of asthma, and in a very small proportion of cases disease of the womb or pregnancy is. Compression of the main trunk of the pneumogastrics by tumors, or their involvement in such growths, has a few times been observed to be causative of the disease. There is not sufficient proof that asthma results from lesions of the central nervous system.

It is more than probable that cardiac disease and Bright's diseases not only predispose to asthma, but that in the course of these disorders there is produced some substance which, when carried to the nervous system by the blood, proves an exciting cause. Therefore in Bright's diseases asthma is generally believed to be uræmic.

Examples of a peculiar form of asthma are rarely seen in which the cause seems to be mental or central, rather than peripheral. I refer to cases in which dyspnœa is caused by fear, or is excited by certain, although the most varied, localities or odors. If such susceptible persons are not conscious of being in the locality of the noxious object, no respiratory discomfort is experienced. These are cases of mental idiosyncrasy, and usually are associated with an hysterical temperament.

Prophylaxis can be applied to a large number and variety of cases. Exemption from the disease is only obtainable by either removing its cause from the sufferer or removing the sufferer from the cause. The latter method is especially applicable to cases of hay fever, in which foreign bodies in the atmosphere are the exciting cause. A change of climate will prevent an attack in such cases. The localities in this country that afford most perfect exemption are the White Mountains, Mackinac, and many localities along the shore of Lake Superior, and numerous places in the more elevated parts of the Rocky and other mountainous regions. Sometimes a residence in the heart of a thickly-populated city will give immunity to individual cases, though they may suffer severely in neighboring suburbs. As these attacks usually occur at certain seasons, especially in August and September, and less frequently in June, temporary changes of abode at these times will give exemption.

A great many medicines have been employed to relieve the dyspnœa of asthma. The best of these are chloroform, ether, chloral, amyl nitrite, nitro-glycerin, or sodium nitrite. They can be made more effective by stramonium, belladonna, grindelia robusta, quebracho, and many other remedies. If taken before an expected attack, the iodides, arsenic, grindelia or senecio aureus will sometimes avert it. Attacks have also been stopped by electrical treatment. Both galvanic and faradic currents have been used and applied in various ways. While successful in most cases when used, our information is as yet too meagre to make it possible to prescribe the currents with certainty. It is best to follow Erb's advice, and

first try the faradic current. The electrodes should be placed on opposite sides of the neck, at points from the angle of the jaw to near the sternum. The current should be a strong one, and should be used from one-quarter to one-half hour. It may also be passed through the chest from the nape of the neck to the cardiac region. When the faradic current fails to give relief, the galvanic can be used. Galvanization of the pneumogastric has been successful. Sometimes the anode and sometimes the cathode is placed over this nerve, *i.e.*, about the middle of the outer edge of the sterno-cleido-mastoid muscle. Weak currents should be used at first. Another successful mode of treatment has been to place the cathode over the sacrum, and to move the anode along the spine for ten or twenty minutes at a time. Schutz also relieved an asthmatic attack by passing a current through the neck, the electrodes being on either side of the thyroid cartilage. Not only has relief been afforded during dyspnœa, but more permanent cures have been effected by daily applications of the current for from one to several weeks. Electricity has proved useful in a considerable proportion of cases, but especially, according to Rockwell, in those most purely of neurotic origin.

Paralysis of Diaphragm.—The diaphragm is rarely paralyzed, but may be (1) from extension of inflammation from the peritoneum, pleura, or pericardium to it; (2) it is often paralyzed just before the fatal termination of progressive muscular atrophy; (3) sometimes by lead poisoning; (4) occasionally by injury of the phrenic nerve; (5) in adolescents cold will, in many instances, cause it; (6) it may occur from unknown conditions.

Commonly the paralysis is bilateral. No movements, or at least free movements, of the diaphragm are possible when it is paralyzed. Therefore, breathing is interfered with. The most characteristic feature is depression of the epigastrium and hypochondrium during inspiration. The respiratory movements are not, as a rule, hurried so long as an affected person is quiet, but upon exertion may become forty or even sixty per minute.

A prognosis depends upon the cause. For example, when hysteria or cold produces it recovery is the rule, but if it accompany progressive muscular atrophy it generally indicates a rapidly-fatal termination to the disease. It does not, of itself, however, cause death.

When this affection is treated the cause should be removed if possible. Counter-irritants upon the epigastrium and along the line of attachment of the diaphragm often have seemed useful. Faradization or galvanization of the phrenics is more certainly useful. This is best accomplished by placing the anode on the epigastrium or along the attachments of the diaphragm to the ribs, and the cathode on the phrenic, *i.e.*, along the outer edge of the sterno-cleido-mastoid, just below its middle. Instead of this, though with less constantly good results, the currents have been passed transversely through the body, at the horizon of the diaphragm. The currents should be moderately strong.

Spasm of the Diaphragm.—Spasm of the diaphragm may be either tonic or clonic. They may both cause death, though the latter rarely does. *Tonic spasm* is a rare affection. It produces within a few minutes intense dyspnœa. A sitting position is almost invariably chosen by those affected. The lower part of the chest is greatly distended, and the epigastrium becomes unusually prominent. The lower half of the chest does not move during respiration, but the upper part moves rapidly, though superficially. The expiratory sound is a short one. This affection, which somewhat resembles asthma, differs from it decidedly in the rapidity of respiration and shortness of the expiratory sounds. The voice is also feeble, and the skin cyanotic. Pain is usually felt in the epigastrium and along the attachments of the diaphragm. The tonic spasm is supposed often to be caused by exposure to cold. It more frequently complicates muscular and articular rheumatism. It sometimes complicates tetany, and occasionally is the immediate cause of death in tetanus.

Clonic spasm of the diaphragm is so well known as hiccough that it needs no description. In most instances it causes discomfort for a few moments only, but it may persist for hours or days, or even, with short periods of respite, for weeks. When persistent, it often hastens death by the weariness that it causes. The cervical spines are frequently tender, in severe cases. Sleep is sometimes impossible, or often short, unsatisfactory, and unrefreshing. Eating becomes difficult; food is imperfectly digested and frequently rejected from the stomach. The lack of sleep, imperfect nutrition, and constant violent motion of the diaphragm produce exhaustion, which may be fatal. Most cases of hiccough are undoubtedly of reflex origin, the stomach, intestines, liver, kidneys, or uterus being the source of irritation. Inflammation of the peritoneum or pericardium and its extension to the diaphragm may provoke hiccough. I have seen it caused by empyema and by an abscess of the liver which had partly eroded the diaphragm. Emotions, such as fear and grief, sometimes incite it. It is also one of the manifestations of hysteria. Cachexias and aneurisms are commonly complicated by it shortly before death. Therefore it sometimes accompanies malaria, chlorosis, and often cancer. Diseases of the central nervous system or injuries to the skull occasionally cause it.

Whenever the cause of spasm of the diaphragm can be removed, it should be. Tonic spasm should be treated with promptness. Relief can often be produced in both forms of spasm by strong counter-irritation in the epigastric region. This can be best and most promptly provoked by the faradic brush, but other means can be employed. The inhalation of strong odors, like ammonia, will often check hiccough. Psychical impressions, such as sudden fright, will also stop it. Persistent holding of the breath is frequently successful in producing relief. Hypodermatic injections of morphia, inhalations of chloroform, or other

anodynes may be employed to relieve the spasm. In hysterical cases the valerianates sometimes help. Galvanization and faradization of the phrenics have also been resorted to with marked success. This should be done as in paralysis of the diaphragm. (See page 7.)

Tachycardia.—Tachycardia is a rapid or forceful beating of the heart which is subjectively recognizable and is not due to organic heart disease. When violent, it is often accompanied by various other symptoms. Attacks of palpitation may last for a few minutes or hours or even days. During the intervals between attacks the heart's rhythm is normal.

Tachycardia is frequently preceded by premonitory symptoms, such as a sudden, apparent stopping of the heart, feeling of terror or apprehension, dyspnœa, slight syncope, vertigo, cold sweat, or headache. During attacks the heart beats with rapidity, sometimes as many as two hundred to the minute. The apex-beat is usually strong, diffuse, and lifting. The sensation of quick, forceful beating commonly excites anxiety, vertigo, etc., or, at least, increases them. Many times the heart is also irregular. Sometimes, at the apex, the first sound is murmur-like or metallic, and the second feeble or almost inaudible. The carotids also often throb violently, and in them a systolic murmur may be heard and thrills felt. The radial artery is generally full and hard, but sometimes is soft and small.

Dyspnœa is a common symptom during an attack of tachycardia. In severe cases it is felt even when the patient is at rest, but in milder ones only when some degree of physical exertion is made. Because of dyspnœa an upright position is chosen whenever palpitation is severe, or at least sudden, in its onset. Fear often makes the respiratory movements irregular. Speech may be jerky, because of the rapidity and difficulty of respiration. Pain is sometimes felt in the epigastrium or under the left breast. The face may be flushed or pale. A temporary increase of temperature is of occasional occurrence. Dizziness and faintness are commoner symptoms. Attacks commonly terminate suddenly. Eructations of gas, vomiting, or defecation often accompany the cessation of palpitation. A persistently quick pulse (about 85) is common in those persons in whom tachycardia recurs often.

That this affection is of nervous origin is not doubted. It is impossible to say in each case what part of the nervous system is chiefly involved. It may arise from anatomical lesions of the brain, such as hæmorrhage or tumors, or from mental emotions, such as fright or joy. Compression of the pneumogastric or sympathetic by tumors or other lesions have been known to cause it. In cases in which there is no anatomical lesion it is impossible to say whether tachycardia is due to paralysis of the heart's inhibitory nerve or irritation of the excito-motors.

Palpitation is often associated with exhaustion of the nervous system by mental overwork, excessive venery, anæmia, or excessive lactation.

General enfeeblement, such as exists during convalescence from many acute diseases, predisposes to it. It is a common manifestation of hysteria. Reflexly it is caused by indigestion, constipation, and by uterine, renal, and hepatic colic. The excessive use of tea, coffee, and tobacco are among the commonest causes of it.

A consideration of the causes of tachycardia makes its prophylaxis self-evident. Hysterical palpitation is often particularly hard to prevent. Sources of fright, or other strong emotions, should be avoided. There are cases in which nervous palpitation recurs frequently without apparent cause. In these cases, and in the purely hysterical, there is much of idiosyncrasy; and relief can often be afforded by devices peculiar to individual cases: for instance, swallowing bits of ice may stop a paroxysm in one person; hot drinks, holding the breath, reclining upon the back, or pressure upon the abdomen in others. What will stop one attack will not always another, even in the same person. Emetics and cathartics will generally relieve those who suffer from indigestion or constipation. So, also, appropriate treatment for various colics may prevent or mitigate the accompanying palpitation.

Tachycardia can often be relieved by an ice-bag over the heart, or counter-irritants. Of drugs anodynes, narcotics, and anæsthetics are the most useful. Valerian and the bromides are especially useful in hysterical cases. Cardiac tonics like digitalis are often inefficient and disappointing.

The constant current has been frequently employed, and sometimes with success, in cases that were stubborn to other modes of treatment. It has usually been applied to the pneumogastrics, first to one and then the other. (See page 1.) Moderately strong currents must be used. The treatment should be employed for a few minutes daily. Usually the subjective sensation of palpitation is relieved before the heart is actually slowed.

Exophthalmic Goitre.—Three symptoms or symptom-groups characterize this affection: acceleration of the heart, a pulsating enlargement of the thyroid, and protrusion of the eyeballs. The disease gradually develops in most cases without premonition. Sometimes it is preceded by a period of malaise, hysterical excitement, or mental depression. Its onset is rarely very sudden. All the symptoms have been known to develop in a single night. They more rarely disappear as suddenly.

A rapid action of the heart is commonly the first symptom. After a variable period the thyroid enlarges and simultaneously, or often a little later, the exophthalmos becomes pronounced. In a small minority of cases one of these symptoms is absent. The exophthalmos is oftenest least marked or absent. The disease usually lasts for months or years. Rare cases have been reported running an acute course. They may terminate fatally or in recovery in two days. Ordinarily the chronic cases are liable to many remissions and exacerbations. Recovery is not

the rule, but may occur. Death is usually caused by complications, but may be the result of marasmus.

The prominence of the eyes produces a staring expression. When it is very great, and the eyeballs are almost protruded through the lids, it is disfiguring. Its production is difficult to explain. An increase of fat behind the eyeball usually exists, but is not sufficient to account for great exophthalmos. The vessels behind the orbit are undoubtedly distended, and form an "erectile"-like body. A vascular thrill can sometimes be felt by the fingers placed upon the eyes. Moreover, the ocular prominence often varies with the heart's rate. It has also been suggested that one factor causative of the exophthalmos may be contraction of the unstriated muscle-fibres of Müller, which run from the eyelid to the membranous lining of the orbit. Spasm of these fibres is the most probable explanation of another ocular symptom common in this affection, and known as von Graefe's phenomenon. If the eyeball is turned downward the upper lid does not follow the movement, as it does in health. The lids are often slightly retracted, but usually cover the eyes completely when they are closed. In rare cases the eyes protrude so much that the lids cannot cover them. This leads to dryness of the cornea and often inflammation of it by external irritants, which the lids cannot ward off. Sight is usually not interfered with. The pupil is normal in most cases, but may rarely be either slightly irregular, dilated, or contracted. Sometimes the ocular muscles are weakened; the internal rectus on one side is especially apt to be. Therefore, if the eyes are bent upon some very near object they may diverge and even produce double vision. The eylids are rarely œdematous. The ophthalmoscope reveals nothing abnormal, as a rule; sometimes the retinal vessels can be seen to pulsate, and the disk may be œdematous. Both eyes are usually equally affected, but one may be exclusively, or more than the other. The degree to which they are affected is variable. Usually it is moderate. The protrusion may be so great that the balls are pushed almost from their sockets.

After death the heart is often found enlarged from dilatation of the left ventricle. Sometimes moderate hypertrophy accompanies the dilatation. Fatty degeneration is not uncommon, but is not extensive. Occasionally slight endocarditis is found to have existed. The heart beats, during the course of Graves's disease, with rapidity and force. Its rate varies from ninety to one hundred and sixty or more beats per minute. Commonly it is from one hundred to one hundred and twenty. In very rare cases it is continuously normal or even slow. Emotion or exertion will greatly accelerate the pulse. Occasionally it is irregular. The heart beats forcefully against the chest. The apex-beat is abnormally diffuse in most cases. The cardiac sounds are commonly loud, sometimes unnaturally so. The heart beats so fast that it probably does not make a complete systole; therefore it gradually becomes overdistended. Even

when hypertrophied, dilatation usually is more marked. The area of cardiac dullness therefore gradually extends to the left, and the apex is displaced in the same direction. Not very uncommonly non-valvular systolic murmurs develop. Sometimes dilatation produces auriculo-ventricular insufficiency, and, less frequently, endocarditis produces a valvular lesion. Pains which radiate from the cardiac region are sometimes complained of. Usually the rapid heart's action is plainly felt by the patient, and may cause distress in the left side. Dyspnœa, especially on exertion, is often experienced. Infrequently a dry, spasmodic cough occurs. The thyroid gland is usually moderately, but unevenly, enlarged. It may be increased excessively. One side is commonly larger than the other. The greater size is due chiefly to an enlargement of the arteries. They are sometimes even aneurismal. The veins are also usually varicose. An hyperplasia of the interstitial tissue and epithelium also occurs, it is supposed, from overnutrition, because of the unnatural engorgement of the tissues. Sometimes cysts are formed in the thyroid body. It is questionable if they and calcification which has rarely been observed in it were not due to pre-existing disease.

The gland pulsates perceptibly. A vascular thrill can commonly be felt in it. Murmurs are audible in almost every case. Frequently they are constant, but made louder by the heart's systole. When the enlargement is very great, discomfort while swallowing may be complained of, and less frequently difficulty of breathing. At first the enlarged gland is soft and elastic, but, as the interstitial tissue undergoes more and more of hypertrophy, it becomes harder. The enlargement of the thyroid often varies from time to time, usually with the pulse-rate. The arteries, especially the large ones, in various parts of the body are apt to be slightly dilated and to pulsate strongly. Systolic murmurs are commonly heard in the carotid, often in the abdominal aorta, and occasionally in the femorals. Patients frequently feel the throbbing. An hepatic pulsation was observed by Lebert. The veins are also frequently distended, and those of the neck sometimes pulsate. Bruit de diable is rarely heard in the jugulars. The radial pulse varies in size in different cases. It is often small, and always soft. Arterial tension is low. Anæmia of greater or less degree exists in all cases of exophthalmic goitre. Hæmorrhages from various organs are of occasional occurrence.

Eichorst confirms Basedow's statement that patients suffering from this disease are often unusually cheerful. My own observations do not confirm this; and I believe most observers will agree that patients are usually extremely apprehensive, so much so that they have become melancholic. The disease generally occurs in those who are nervous or hysterical, and thus aggravates these neurotic states. Neuralgias, shifting and of variable severity, are frequently complained of. Those who suffer from the disease are usually thin, and, so long as the disease grows worse, they lose flesh and strength, especially endurance. Derangement of

nutrition is sometimes indicated by falling of the hair, by maculation of the skin, and, in rare cases, by gangrene of the feet. Excessive perspiration or unilateral perspiration, persistent weeping, salivation, and the excretion of excessive quantities of pale urine, of low specific gravity, frequently indicate abnormal glandular activity. Glycosuria is occasionally observed to complicate Graves's disease.

The bodily temperature is usually normal, although at times it is slightly and irregularly elevated. Appetite is variable. Digestion may be disturbed as an accidental complication, or by the mental depression which so often accompanies exophthalmic goitre. Menstruation is usually irregular or suppressed. The disease occurs twice as often in women as in men. It is rare in childhood, and commonest between the fifteenth and thirtieth years. It often develops in those who have been weakened by prior illness. A nervous temperament undoubtedly disposes to it, for hysteria, epilepsy, and other nervous diseases often precede and accompany it. Statistics bearing upon its geographical distribution are few. It is, however, undoubtedly true that the disease is common in some localities and rare in others.

A satisfactory explanation of the cause of this disease has not been made. It is undoubtedly due primarily to a lesion in the nervous system. The cervical sympathetic has been carefully examined as the possible sight of a lesion. It has not been found to be uniformly affected. It seems more probable that the central nervous system is the part involved. Most authorities believe that the cervical sympathetic is directly, or through the brain indirectly, involved. It is, however, very difficult to explain the origin of the characteristic symptoms simply by a derangement of these nerves, and still more difficult to explain the rare atypical cases.

Cardiac tonics, like digitalis, are almost always disappointing in their effects. This is equally true of ergot, the iodides, arsenic, and iron. The latter will sometimes help. I have no doubt that the iodide of iron and ergot helped to produce in one of my own cases a feeling of well-being that amounted almost to a cure, and was permanent for eighteen months, after which time the patient was lost sight of. But electricity has proved more uniformly useful than any other agent. A weak galvanic current is usually applied over the cervical ganglia. The following directions are given by Eichorst: The cathode should be applied high up on the neck, and the anode between the scapulæ. The current, from 5 to 10 elements, should be allowed to pass between these points for two minutes. Then, with the anode still upon the cervical spine, the cathode should be placed over the sympathetic and pneumogastric, upon each side, for two minutes. It should first be placed in the auriculo-maxillary fossa, and gradually drawn down along the inner edge of the sterno-cleido-mastoid to the clavicle. I have applied the current in this manner to one case. A diminution of the pulse-rate was

produced by the treatment, but the case was not long enough under treatment to determine the real value of the method. I permitted the current to pass, for about four minutes, through the nerves on each side of the neck. An immediate reduction in the pulse-rate has usually been observed on galvanization of the sympathetic, but not always. In a small minority it has remained unchanged, although, even in these cases, the struma and exophthalmos have lessened and general health has improved. Numerous cases have been reported as nearly or quite cured by this mode of treatment. Usually the current must be applied many times; for instance, daily for two or three months. As the locus of the disease is more probably in the medulla than the nerve-trunks, galvanization of it has been attempted by passing currents transversely through the back of the head, just above the spine. Transverse currents have been passed through the goitre for a direct effect upon it. The enlarged gland has been punctured by electrolytic needles, with the hope that it might thus be reduced. The results have varied. On the whole, I judge they have not been very satisfactory. Erb has tried the application of very mild currents to the eyes: one pole was placed on the closed eye and the other at the back of the neck, and later the poles were placed upon each temple. But he says, "I cannot venture to say whether it was of any real use."

The life of the patient must be carefully regulated. Excitement and overexertion must be avoided. Cheerful companions and pleasant surroundings should be provided if possible. Stimulants and strong tea and coffee should not be taken. Simply-prepared but varied food should be supplied, and better general nutrition cultivated by every possible means. Change of climate, baths, the drinking of ferruginous waters, or an out-door life in a balmy air, often produce wonderful improvement in these patients. Several recoveries have been reported that apparently resulted from pregnancy or childbirth. Complications, as conjunctivitis and corneal ulceration, often require special treatment. Excessive palpitation can sometimes be lessened by an ice-bag upon the pericardium. Ziemssen has suggested the treatment of the heart with strong galvanic currents to lessen its rate, but Erb urges caution in their use.

Angina Pectoris.—The characteristic symptom of angina pectoris is the pain which gives it its name and the agony which it produces. The pain is felt to originate or centre in the cardiac region. From this region lancinating pains radiate, especially toward the left shoulder, sometimes along the left side of the neck or face, and more frequently into the left arm, and even to the fingers. Rarely pain is felt about the right shoulder or in the abdomen. The main pain, when sure, is intensely agonizing. It is described as a persistent, squeezing pain; sometimes as tearing or burning. A feeling of anxiety and of impending death is peculiar to this variety of neuralgia.

The pain often makes its onset suddenly, without premonition. A patient may be awakened with it. In other cases it only comes on after physical or mental exertion. Rarely the attack of pain is immediately preceded by vertigo, tinnitus aurium, chilliness, or some other variable symptom. In some instances the pain gradually increases in intensity, or oftener it is severe from the start. It may also cease gradually or suddenly. Its cessation is sometimes associated with gaseous eructations from the stomach, or movements from the bowels. Attacks of angina may occur daily, or only after intervals of months or years. The pain sometimes persists for days together, but more frequently for a few minutes or hours only. Its severity varies greatly. It may be so trifling as to excite little comment, until after a fatal attack its significance is recognized. Usually, and in all characteristic cases, it is intense. The painful areas upon the breast, neck, and arm are often hyperæsthetic. During the intervals, if the breast-pang is not secondary to organic heart disease, a patient may feel perfectly well. Undoubtedly the angina is a neuralgia of the cardiac nerves. They are sometimes found involved in anatomical lesions; for example, in inflammatory, cirrhotic, or degenerative states. Oftener hidden changes in nutrition or metabolism are the cause of pain. The numerous anastomoses of branches of the cardiac plexus with especially the left brachial and the neighboring nerves of the neck account for the pain which radiates out from the heart or courses up the neck or down the arm.

The heart usually beats tumultuously during the paroxysms of pain. At times, however, its rate is little affected. When the pain begins, the heart is apt to beat rapidly and forcefully, so that its apex-beat will appear diffuse and strong upon the chest and its first sound will be short and accentuated strongly. But soon the agony causes depression amounting almost to collapse. The heart beats fast, but feebly; its sounds are weak. The apex-beat is only dimly visible. The pulse at first may be full, though it soon becomes small. It is, however, rigid. Breathing is often superficial, irregular, and accompanied by frequent sighing. Such respiratory perturbations are of reflex origin from the pain. A patient suffering from angina pectoris exhibits the countenance of one in great agony or fear. His face is usually pale, and, when the pain is hardest, the skin is commonly covered by a cold, clammy sweat. The intensity of the pain must not be regarded as a criterion of the danger to life. For instance, a gentleman, who had been my patient for a year, died suddenly recently during an attack of angina. He had during the preceding year suffered from many mild ones; several times daily the cardiac pain was felt,—indeed, whenever he walked or exerted himself more than very moderately. Another patient I recall, who, for eight or nine years, has had occasional, very severe attacks and still lives. Many patients lie as quietly as possible, or gently roll from side to side, groaning; others prefer to stand, or cling to a mantel, table, or chair-back, or,

because of the feeling of thoracic oppression, seek an open window or door. Sometimes, during these attacks, or immediately after them, large quantities of urine of low specific gravity and limpid aspect are made. Rarely, at these times, it contains sugar.

Death may result from marasmus, but more frequently is due to heart-failure, cardiac rupture, cerebral hæmorrhage, or other intercurrent disease. Several varieties of angina pectoris have been named upon theoretical grounds. They cannot be recognized clinically satisfactorily. In one group of cases angina is secondary to such lesions as atheroma of the aorta or coronary arteries; aneurism of the aorta; insufficiency of the aortic valves, less frequently of the mitral; fatty degeneration of the heart-muscle, obliterating pericarditis, or mediastinal tumors. In another it is idiopathic. Sometimes these latter will follow exposure to cold, and are supposed to be due to the increased arterial tension which results from the simultaneous contraction of the peripheral vessels. Attacks also often follow excitement. They are occasionally associated with hysterical manifestations, hypochondriasis, epilepsy, insanity, and other disturbed conditions of the central nervous system. The excessive use of tobacco or alcohol seems sometimes to be a predisposing condition. Gout, rheumatism, and syphilis are general diseases that are often associated with angina pectoris. It occurs with sufficient frequency in some families to seem inheritable. Attacks occur most frequently after the fiftieth year of life. Three-fourths of all cases are among males. It seems commonest in cold and changeable climates, though the statistics bearing upon this point are not abundant.

When angina pectoris is due to disease of the heart or arteries, these lesions must be appropriately treated, and, if successfully, relief may be obtained from attacks of breast-pang. Often the cause or condition provocative of the pain cannot be discovered, and, therefore, cannot be removed or treated. The use of tobacco and alcoholics should, as a rule, be forbidden those who suffer from this disease. Excitement and great physical exertion should be avoided.

At times ice, applied over the heart, will relieve temporarily the pain. More frequently counter-irritants will accomplish the same result. Therefore sinapisms are very generally resorted to. The faradic brush, as it excites counter-irritation more promptly and efficiently, has frequently given the greatest relief. Duchenne has claimed permanent cures by the persistent use of the faradic brush over the sternum and heart.

Galvanism certainly promises more than medicinal treatment. It usually gives very prompt relief, and its persistent use has many times appeared to produce a permanent cure. This is especially apt to be true in the idiopathic cases. The current has been applied in several ways, with apparently equally good results. The positive pole with a broad surface has been placed by Eulenburg over the heart and sternum, and

the negative on the lower cervical vertebræ. The current passed between these points was gradually increased until 30 cells were brought into the circuit. Von Huebner placed the positive electrode in the suprasternal fossa, and the negative upon the cervical sympathetic ganglia, of first one and then the other side; he then moved the positive pole to the lower cervical ganglion and the negative to sensitive spots, at the angles of both shoulder-blades. At first, weak currents, from 4 to 6 elements, were used, but gradually their strength was increased, and 8 or 10 elements were employed. The neck may be galvanized also by placing the cathode with medium-sized surface at the angle of the jaw, over the superior cervical ganglion, and the anode, with an electrode of larger surface, upon the base of the neck. The currents should be gradually increased in strength. By most not more than 10 or 15 cells are used. The duration of the application of the currents must also be gradually increased. Usually from one to five minutes are sufficient for its use.

For the immediate relief of pain, such drugs as morphia and chloroform are frequently used, with good results. The nitrites, by dilating arterioles and relieving blood-pressure, also give relief with promptness. The nitrite of amyl acts most quickly, and nitro-glycerin and nitrite of soda act more persistently. A great many drugs have been employed to produce permanent effects. Alteratives and tonics have been used the most. The published results obtained from these have varied so much that their utility seems doubtful. The mode of life of patients should be so managed as to insure them as good, vigorous, general health as possible.

Intercostal Neuralgia.—The pain of intercostal neuralgia may be felt anywhere over the thorax, but occurs oftenest upon the left side and below or just about the breast, or under or between the shoulder-blades. It is much less common about the upper part of the chest than the lower. Sometimes the pain radiates toward the shoulder, neck, or inner side of the arm. In character it is usually stitch-like or lancinating. When very severe, it is dull, constant, with paroxysms of a penetrating or lancinating character. It is sometimes described as piercing like a knife-thrust, burning, or tearing. When moderately or severely sharp, tenderness is felt to firm pressure over the affected nerves near the spine and near the sternum and about half-way between these two points. In the area supplied by the affected nerves there is sometimes anæsthesia or hyperæsthesia. If the pain is not constant or hard, tenderness is frequently absent. Respiration is usually shallow when the pain is hard, and occasionally is quickened. In some severe cases the affected side is held as still as possible, and the shoulder is permitted to drop. Patients are frequently much frightened by intercostal neuralgia in the region of the heart, and attacks of hysteria are often precipitated by it. The heart beats normally, unless fear should temporarily hasten it. An eruption of zoster indicates neuritis.

Intercostal neuralgia can be distinguished from pleurisy by the absence of the physical signs of that disease—fever and causes such as produce inflammation of the lungs. From muscular rheumatism it is distinguished with more difficulty. Both conditions are usually aggravated by deep breathing, coughing, or sneezing. Movements of the arms are more apt to aggravate muscular than neuralgic pain. If there is tenderness when the muscles are affected, it is at their insertions, not at the three points characteristic of neuralgia. The cardiac disturbances, the great anxiety and dread of angina pectoris, the intensity of the pain and its radiation toward the shoulder, distinguish it from intercostal neuralgia, though not infrequently both co-exist. This affection is always recovered from, except in some very chronic cases. A return of the trouble is very common. It occurs somewhat oftener in women than men, and most frequently between the ages of twenty and forty. Weak, anæmic, nervous, and hysterical persons are most liable to it. Such diseases as chronic constipation, gastric flatulence, phthisis, and lesions of the vertebræ and spinal cord commonly cause or dispose to it.

A cause for the affection should be diligently sought, and, if found, removed when possible. Counter-irritants will often stop the pain. Of these, the faradic brush acts most promptly. Opiates or narcotics must be used in the most intense cases. Galvanization will often relieve more promptly and permanently. The anode is usually placed on the vertebra and the cathode near the sternum, over the affected nerves; and, if there is a lateral tender point, also over it. The current should be strong. From five to ten minutes should be used for the application. The pain is usually relieved by the first galvanization, but for its permanent relief several daily applications are usually required.

DISEASES OF THE UTERUS.

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Chronic Inflammation of the Uterus.

Introduction.—The duties of a writer on the uses of electricity in inflammatory diseases of the uterus are but illy discharged if he neglect to present a summary of the nature of these affections and call attention to their relative importance in pelvic disease. Such a summary and reminder are the more necessary now, also, because of a pronounced neglect of this important initial lesion in pelvic disease in favor of the more attractive conditions usually treated by major operations. This relative neglect may be also due to the inadequate means of cure heretofore possible, the failure to cure chronic uterine catarrh having led to an attitude with some that denied the abnormality of the condition. Many facts in the experience of bacteriologists and clinicians teach us, on the contrary, that these catarrhal discharges are abnormal when they depart from certain characters in appearance, consistence, quantity, bacteriological qualities, etc.; and that they are, in reality, both evidence of distinct local disease and fruitful of disease consequences in neighboring organs and the general organism. Chronic endometritis, in other words, leads to chronic metritis, salpingitis, ovaritis, and perimetritis by direct transference through contiguity of structure. The most common diseases of the appendages (which, in spite of their importance, have attained such undeserved prominence of late) are essentially catarrhal in origin and secondary to catarrhal inflammations of the uterine mucous tract, not even exclusive of tuberculosis and the conditions leading to ectopic gestation, which are supposed to be invited and fixed in an inflammatory nidus.

For practical purposes, particularly for an intelligent application of electricity to the exact seat of disease, it is necessary to continue the division of endometritis and metritis into several varieties, each presenting peculiarities of macroscopic and microscopic appearances mainly due to the histological structure of the particular portion of the organ; but it should be stated, at once and distinctly, that the views now held by most progressive thinkers, and concurred in by the writer, class all varieties alike as microbic in real character, and hence pathologically identical, except as varied by the particular microbe concerned and the local structure. Such views are as yet wanting in recent editions of some standard text-books on gynæcology, which retain older classifications based on the physical appearances of the attacked membrane,

unmindful of the fact that such appearances are often merely indicative of the stage the disease has attained.

Granting the causative relations of bacteria to uterine inflammations, their modes of occurrence are, in the main, patent, including the direct implantation of germs in coitus, by unclean instruments, etc. There are, nevertheless, a great number of cases in which such modes of implantation can be absolutely excluded, particularly in the instances of virgins not even guilty of masturbation. The explanation is two-fold, and embraces the well-demonstrated facts of phagocytosis discovered by Metchnikoff, on the one hand, and, on the other, the fact that the vagina and cervix, as far as the internal os, is normally the habitat of pathogenic germs.[1] The absence of these apparently dormant germs from the uterine cavity is significant, and indicates the probability of a special barrier of phagocytic sentinel-cells in or about the internal os. As long as the general health is maintained these cells are able to repel the constantly threatened invasion from below, but with a deterioration of health this resisting power is undermined, and we have the intra-uterine irritation and leucorrhœa, with its attendant menorrhspasm, so frequently found in weak, anæmic young girls. Therein lies the third element in a catarrhal attack, as interpreted by modern views, which explains our every-day knowledge of "catching cold." Given a germ in contact with a mucous surface, under the conditions constantly present in certain bodily cavities, why does not a catarrh—*i.e.*, an irritative reaction of tissues consequent upon a germ-phagocytic contest—perennially exist? The only possible conclusion is that a nerve-tonus existing normally is in some way lowered by the exposure to cold, wet, or traumatic influences, resulting in a lessened protective power in the phagocytes. These facts explain the spontaneous cure that may attend a restoration to health in moderate cases, and also the failure of traumatism to cause inflammation in rare instances when the health is good and the virus attenuated. The source of the germs found normally in the secretions of the vagina and cervical canal is unquestionably external and possibly often atmospheric, for the ubiquity of the most common bacterium of pus, the staphylococcus pyogenes aureus, has been proven by many observers, particularly in cities and other centres of population.

The conditions brought to the notice of the clinician whenever a case of any form of metritis engages his attention, therefore, are essentially *the products of germ action and tissue reaction.* How electricity may be brought to bear as a curative agent is best understood after a rational contemplation of its influences upon these two elements in the disease: the one—germ action—being the original and continuing cause; the other—resultant tissue changes—being the disease itself as an appreciable entity to patient and physician.

[1] See the researches of Hausmann, Küstner, Lomer, and Bumm, quoted in Pozzi's Gynæcology, vol. i, p. 160.

Bactericidal Action of Electricity.—The influence of the constant galvanic current on the vitality of microbes has been investigated by Schiel, Cohn, and Mendelssohn, and most recently and thoroughly by Apostoli and Laguerrière.[1] The latter observers made a most thorough study of the subject during a series of fifty-two experiments on the microbes of anthrax, pus, and various non-pathogenic varieties, in which 140 guinea-pigs, 42 rabbits, and 2 dogs were killed. The apparatus found best adapted to the determination of the action of each pole upon cultures of various microbes in broth is shown in Fig. 1, by the use of which it was possible not only to isolate the action of each pole in its tube, but also to test the interpolar effect adjacent to each pole. As was to be expected, the passage of strong currents from the surface of small platinum spirals through the peptonized broth caused a decided rise of temperature, particularly at the positive pole. In some of the experiments this thermal influence was eliminated by placing the apparatus on

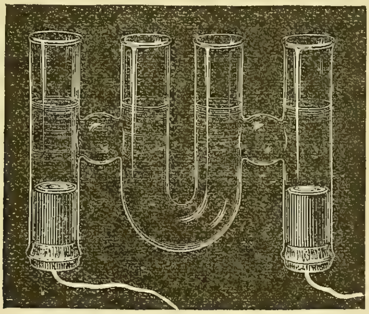

FIG. 1.—APPARATUS FOR TESTING THE BACTERICIDAL PROPERTIES OF ELECTRICITY.

ice. In others the chemicals liberated at each pole were eliminated, either by the use of an absorbent, as magnesium or lead at the positive pole, or by being covered with gelosine. The results showed a distinct attenuation or destruction of the microbes when currents of more than 50 milliampères were used five minutes. Beneath that dosage the action of the positive pole actually increased the virulence of the microbes, doubtless by reason of the addition of free oxygen to the media and a moderate increase of temperature. It was further proven that neither the negative pole nor the transmitted current through the interpolar region exerted any influence on the vigor of cultures, and that the action at the positive pole was entirely dependent on the nascent chemical products and the heat that were developed.

These carefully-conducted experiments must certainly discourage the use of galvanic applications as germicides, *per se*, in the cavity of the uterus, since current-strengths entirely sufficient to cure certain

[1] De l'Influence du Courant Continu sur les Microbes, par MM. Apostoli et Laguerrière. Reprint, Paris, 1891.

cases do not develop this quality, and in this disappointment we but follow the experience of antiseptic therapeutics elsewhere within the body-cavities. They prove, nevertheless, that where currents exceeding 100 or 150 milliampères are called for in their curative capacity we may also anticipate a direct microbicidal action accompanying them, if the electrode surface is small enough to intensify the action. It need not be said that this much is a great comfort, and that in the extension of the current-strength to the ampèrages used in cancer, for instance (400 to 600 milliampères), we also employ a most efficient and thorough antiseptic application.

For antiseptic action in currents of 50 milliampères and under we must rely upon antiseptic cataphoresis, in which it is possible that minute currents may be made efficient by surrounding the active pole with a cotton covering holding such substances as a dilute solution of corrosive sublimate, creasote, iodine, etc.

Alterative Action of Electricity.—Whatever conclusions are arrived at relative to the bactericidal action of electricity, it should not be forgotten that the final cure of any form of metritis necessitates the alteration of abnormal nutritive processes which may have caused, and certainly have resulted from, the bacterio-phagocytic contest. The actual conditions found in cases of established endocervicitis, endometritis, or metritis are practically all instances of tissue proliferation. Nature must be stimulated and assisted in the removal of this altered material, and where the abnormal conditions are still mainly confined to the mucous membrane, as in catarrhal, glandular, and vegetative varieties, at least a slight portion of the curative action of electricity is the direct destruction of the added tissue by the electrolytic decomposition that accompanies the polar action of a galvanic current. The morbid surface, as a whole, is subjected to a controllable destruction, wherever in immediate contact with the electrode, by a resolution into its ultimate chemical constituents of acids and bases. This destructive action of electrolysis is, on the surface, somewhat analogous to the destructive action of the same acids and bases applied directly to the part, as a portion of the cauterant action of electricity is due to the nascent chemicals liberated by it in electrolysis of animal substances; but to this is added a tissue stimulation peculiar to electro-chemical cauterization yet imperfectly understood.

The cauterant action differs in character at each pole, as is well known, that at the positive pole being acid in reaction, whitish in color, and surrounded by a little froth that consists of oxygen-bubbles. If carried to some extent a more or less superficial necrosis will result, which is drier than surrounding tissues because of cataphoresis. At the negative pole a current-density sufficient to cauterize freshens the surface, produces a brighter color, and gives rise to an abundant froth of hydrogen-bubbles. If carried to some extent an increase of liquid by cataphoresis is manifest at and around the negative pole, and the tissues

in immediate contact are softened and finally dissolved to an extent corresponding to the milliampères used, and their density and duration. The reaction is alkaline.

The possibility of producing this galvano-chemical cauterization of the endometrium in an intra-uterine application depends on the current-strength and duration, to which it is directly proportional, and on the extent of bare surface on the active electrode, to which it is inversely proportional. With an ordinary sound-shaped electrode, having a bare surface extending two inches back from the point, 20 milliampères may not cauterize in three minutes, but may cauterize slightly in five minutes. Fifty milliampères can be used with a bare electrode of greater size in the vagina under the same conditions, with about the same result. On the other hand, $\frac{1}{2}$ to 1 milliampère, applied on the point of a fine needle as in the epilation of hairs, will cauterize in a few seconds. The direct application of the bare surface of the electrode also influences the cauterant action of the current, by reason of the sudden change of conductivity, a current that would cauterize with a bare electrode being quite inadequate to do so when covered with a proper thickness of liquid-retaining material such as clay, wet absorbent cotton, etc. In this case the current-strength or duration must be sufficient to carry the cauterant action through the covering, else the tissues merely receive a concentrated interpolar action,—a result at times more desirable than actual cauterization.

An additional feature attendant upon the local action of a galvanic current is the temporary alteration of the nerve-tone in the filaments under the influence of either pole, that at the negative being stimulant (katelectrotonus) and at the positive at least temporarily sedative (anelectrotonus).

Lastly, the cataphoretic action of the current deserves attention, as it presents features only lately recognized as of considerable importance in this class of cases. Like electrolysis, to which its phenomena are intimately associated, it is only appreciable in connection with the galvanic current. The chief evidence of this action is the actual transfer of liquids and solids through the body from the positive to the negative pole. This results in a progressive desiccation of the electrode coverings and tissues about the positive pole, and a corresponding increase of moisture and congestion at the negative. With 50 milliampères passed from a cotton-covered vaginal electrode for two or three minutes, this action is quite apparent, and is more quickly manifested when the conducting surface of the active electrode is smaller, as in intra-uterine applications. So great is the dryness at the positive pole when this polar surface is minute, as, for instance, a needle-point, that it becomes quite impossible at times to overcome the added resistance sufficiently to get the desired current through. The practical effect of the corresponding accumulation of water at the negative pole is a considerable increase in

the local circulation in its neighborhood, and a resultant stimulation of vital processes. The local anæmia at the positive pole is sedative and inhibitory of vital exchanges.

Allusion has been made to the facts that solids are also physically transferred from the positive pole inward toward the negative. The very particles of the electrode itself will be caused to penetrate the flesh if the operator has unwisely employed a base metal as the positive electrode, the products of electrolytic erosion of the metal being sent into the tissues. Even carbon electrodes are not entirely proof against this action, as small particles are at times detached from the softened surface and caused to penetrate somewhat. Therapeutic advantage is taken of this "anodel diffusion" of basal substances from saline solutions applied on the positive pole, such as cocaine, iodine, etc., and this medicinal cataphoresis, which has been used by Peterson, Hunter McGuire, Goelet, Briggs, and others, offers an interesting field for medicamental and antiseptic additions to the galvanic applications *per se*. Cataphoretic medication is, however, not confined to the action of the positive pole, as certain substances, by reason of their chemical affinities, will enter the body from the negative pole under the action of electrolytic decomposition.

VIRGINAL ENDOMETRITIS.

Adopting a purely clinical classification of uterine inflammation for convenience in considering the practical uses of electricity, a most important group is made up of the uterine catarrhs of young girls, already alluded to. This form is by no means infrequent, as it accompanies and bears a causal relation to a considerable proportion of the cases of menorrhspasm (dysmenorrhœa) which are so common at this time of life. Electricity may be made an important feature in the hygienic and medical management of such cases, which should almost invariably be employed before even a local examination is made. Remembering that an actual invasion of the uterine cavity may be repelled by measures that assist the natural defenses of the tissues, we should supplement a proper hygienic and medicinal regulation of the abdominal and pelvic functions by the addition of stimulant applications of the galvanic current to the abdomen by means of large electrodes on the back and hypogastrium. Currents of 20 to 100 milliampères may be used at frequent intervals, the patient lying on a large indifferent pad with the more-active, negative, electrode on the abdomen, the latter being a well-moistened pad at least six inches in circumference.

But, if the endometritis is too firmly intrenched to yield to these constitutional and relatively general measures, and the case bids fair to lead to the chronic "ovarian" disease that has brought so many of these girls to the operating table by the portal of the Fallopian tubes, we must explore the pelvis by touch, and endeavor to determine the presence of sufficient enlargement of the uterus to warrant intra-uterine exploration

and treatment. The use of a speculum of even small dimensions is to be avoided if possible, as it is by no means essential that vision should assist the *tactus eruditus* of an experienced hand. If the uterus is found to be fixed by adhesions, moreover, the use of the sound demands extreme caution, if it be employed at all.

It may be predicated that no endometritis warrants direct treatment unless metritis be associated with it; hence an enlargement shown by palpation will be the clinical indication for exploration and local treatment. This must usually be done with the Simpson-shaped electrode (Fig. 2)

FIG. 2.—THE MASSEY INTRA-UTERINE ELECTRODE, WITH FUSIBLE INSULATION OF SHELLAC.

with as large a tip as can be inserted, as it will usually be impossible to insert the elastic instrument (Fig. 3) always employed in preference by the writer when the canal is sufficiently large. A little patience will be rewarded with a successful insertion in any case, the instrument to be passed along the finger by touch in the gentlest manner, the patient being in the dorsal position on a table of proper height. In an experience of many cases I have never been compelled to use a tenaculum or speculum for such a purpose. As for the too-usual practice of employing instrumental dilatation, either to render the insertion easy or as a remedial measure, I cannot speak too unqualifiedly in its condemnation. The dilator is necessarily larger than the electrode, any way, and the force required to insert it is more than necessary for the insertion of the elec-

FIG. 3.—THE MASSEY ELASTIC PLATINUM INTRA-UTERINE ELECTRODE, WITH FUSIBLE INSULATION OF SHELLAC.

trode itself. Its use for such a purpose would be merely an absurdity, if this effort to make a medical case surgical did not frequently lead to harmful lacerations of the substance of the cervix.

Concerning the use of dilatation as a remedial measure, either with the ordinary dilator or by graduated electrodes, it may be pointed out that the canal is amply large enough to give exit to all discharges in these cases, the obstructive theory of menorrhspasm having been completely disproven by Schultze and others.

Unless a menorrhagic condition complicates the endometritis, which is unusual in the class under consideration, the negative pole will usually be found to be best for the active electrode, as favoring drainage by cataphoresis, and less likely to produce erosion of the mucous surface.

The current-strength may vary from 10 milliampères in mild cases to 40 milliampères in the more inveterate, for three or five minutes. Such applications should be followed by intervals of no treatment, or of vaginal applications, lasting from five to seven days.

Should the endometritis be complicated by a salpingitis or other peri-uterine inflammation, as evidenced by a fixation of the uterus, all intra-uterine exploration or treatment should usually be postponed as unsafe, and recourse be had to vaginal applications of from 50 to 100 milliampères negative, which may quickly restore the uterus to a movable condition. After this result appears it may still be necessary to make tentative applications to the uterus, under circumstances involving the possibility of rest following the treatment.

POST-PUERPERAL METRITIS; SUBINVOLUTION.

Arrested involution of the post-parturient uterus, whether due to inertia, non-traumatic infection, or traumatic infection, is more successfully and quickly treated by electricity than by any other means at our disposal. It is even a question whether normal involution would not be materially hastened by the systematic application of faradic currents to the highly contractile tissue still constituting the bulk of the uterus, as advised by Apostoli. Certain it is that when the natural process is sluggish by reason of a diminished rate of shrinkage in the muscular fibres, a few applications of the faradic current from the primary or a coarse secondary coil will stimulate the flagging muscular tissue to develop its normal tone. Sanguineous discharges continuing beyond the normal periods of their appearance, or recurring during the first weeks after parturition, may be controlled by from one to three such applications; and if there is no sepsis or traumatism as a causative factor, no other treatment is necessary. For these applications I prefer the monopolar method; and the softened walls of the uterus and its patulous condition render the use of the elastic platinum electrode the least irritating, either bare or covered with cotton steeped in a medicated solution.[1] Apostoli, Goelet, and others employ bipolar intra-uterine faradic currents (Fig. 4) for this purpose; but I have found it difficult to asepticize the electrodes satisfactorily, and have always obtained good results from the monopolar applications.

But it is rare for subinvolution to be of so simple a nature—shreds of retained decidua, a morbid condition of the endometrium, a laceration, or other traumatic accident, being the determining cause of a septic endometritis, to which the subinvolution is due. In these cases the galvanic current is indicated,—the positive pole of carbon if the hæmorrhagic feature predominates, though unless the hæmorrhage is considerable the

[1] It may be well to state here that the writer, while but rarely using antiseptic douches immediately before inserting an electrode within the uterus, invariably sterilizes the instrument itself, and with the direct flame of the alcohol-lamp whenever possible.

covered elastic electrode is best. The swelling method (gradually increasing and diminishing alternately) should be employed, with a dosage varying from 25 to 60 milliampères, according to indications. To this the faradic current may also be added.

For a septic condition of the uterus the positive pole is the most satisfactory, and if the sepsis is accompanied by but slight portions of retained decidual membrane it is quite unnecessary to resort to the risks and loss of blood attending the use of the curette. The drainage that follows a galvanic application will usually be amply sufficient to carry off these shreds when detached by the action set up by the current, but

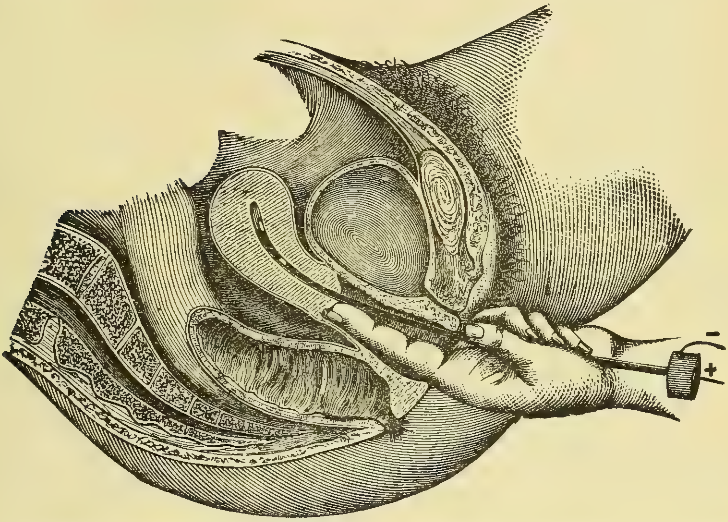

FIG. 4.—APOSTOLI BIPOLAR INTRA-UTERINE ELECTRODE IN POSITION FOR FARADIC APPLICATION.

if the decidual remnants are large and abundant the curetting operation should be used before the alterative and contracting applications are made.

CATARRHAL METRITIS; METRO-SALPINGO-OÖPHORITIS.

An endometritis in parous women is more apt to be associated with interstitial infiltration of the parenchyma; at least, in the stages in which it comes under the observation of the specialist. Extension upward into the tubes and to the ovaries is common also; so common, in fact, that the resulting salpingitis and oöphoritis are now too often considered as the only diseases existing, in many cases in which they are yet secondary to the metritis. Large numbers of such cases have come under the writer's observation in that stage in which the too-ready knife of the cœliotomist has removed relatively inoffensive appendages, leaving untouched the true seat of the disease. Such mistakes are largely due to misinterpretation of the subjective symptoms of pain and tenderness

elicited on rough, bimanual examination, when uterine tenderness is easily mistaken for ovarian tenderness, particularly if the examiner's mind is so constituted as to habitually overlook the possibility of a metritis existing.

Beginning as an endocervicitis or a general endometritis as a result of septic invasion from gonorrhœa or other microbic agency, under the developmental stimulus of a "cold," the patient is only conscious at first of a leucorrhœa, which becomes more abundant and irritating to the vagina and vulva, and should be the sign for active electrical treatment on the part of her physician, though of late a do-nothing policy has been advocated by some. It has been said by an authority that the womb has its secretions, like the nose That is true, of course, but it should be remembered that the nasal secretion is not normally muco-purulent; as soon as pus-corpuscles habitually occur in either secretion, the existence of a diseased condition is manifestly proven.

The subsequent stages and the effects of this catarrhal endometritis are natural consequences. Accompanying the hypertrophy of the endometrium into fungoid and cryptose conditions, we have a direct stimulation of the connective-tissue cells of the parenchyma. Trophic changes in this situation and general fibrosis result. Coincidently, or at a later period, an extension upward along the mucous tract occurs, and salpingitis, ovaritis, or both, add their burdens to the suffering woman. I shall not recount the local symptoms of this conglomerate affection beyond the statement that at various periods in its course we find changes in the quantity and quality of the secretions, erosion of the os from irritating discharges, followed possibly by an hypertrophy and tenderness without leucorrhœa, the uterus remaining reasonably movable. On the reflex symptoms some doubt has been thrown of late, but the best proof that pains down the limbs, in the abdomen, and in the back, with or without nervous prostration, are caused by this "irritable" uterus is given by the disappearance of such symptoms as the result of local treatment. The reason for the doubt lies at times in the lack of neurological training in many gynæcologists, who have mistakenly treated such diseases as hysteria, neuralgia, lateral sclerosis, locomotor ataxia, and even scoliosis, in the writer's experience, as mere nervous manifestations of pelvic disease.

Besides errors of diagnosis, it is possible that the present tendency to minimize the effect of uterine disease in causing backache or other neuroses is due to the failure to cure such conditions by removing scar-tissue from the cervix. Failing to cure these cases by cutting out this harmless reparative effort of nature, and by removal of the appendages, the remainder of the woman is kept in bed for long periods of time, under the theory that the "rest-cure" was the proper thing after all, and that rest was the most essential part of the rest-cure.

For therapeutic purposes these forms of chronic metritis are divisi-

ble into two classes that much resemble the divisions made by the late George M. Beard in cases of sexual neurasthenia in the male. In the one class the affection occurs as a purely local disease, the nervous organization of the individual being so robust that it fails to become affected by the local disturbance; in the other class a far less degree of local trouble may be found, associated with profound depression and disorder of the nervous system,—a disorder that seems greatly disproportioned to the local disease.

The electrical treatment of the first class of cases is naturally entirely local, and may generally be carried out in the office, when the disease has not yet ascended to the tubes and ovaries. Intra-uterine applications may be begun at once, but when so begun they should be regarded as an Apostoli test of the existence of a perimetric inflammatory extension, which would debar their continuance if pain or the temperature were markedly aggravated. The safer plan is to make vaginal applications only at first, and later to apply the intra-uterine applications tentatively, and with weak currents (15 to 25 milliampères), and preferably by means of the elastic electrode covered with a thin layer of cotton saturated with a weak antiseptic solution. A little skill in covering the electrode will enable one to do so neatly, and in such a way that the additional bulk will not prevent its insertion into an ordinarily patulous canal, or make it possible to leave the cotton in the uterus. With the elastic platinum electrode (Fig. 3), which is the only one used covered by the writer, the difficulty is to get the cotton off afterward if the terminal bulb of the instrument is not quite small. If it does not loosen sufficiently to slip off under running water it may be burnt off in the spirit-flame; violent pulling will ruin the instrument.

As muscular relaxation is generally an element in all these cases, the faradic current of quantity may be added to the galvanic treatment, either simultaneously through a combiner or immediately afterward.[1]

It should be needless to say that the harsh methods of examination and treatment too prevalent at present should be avoided, particularly the unnecessary stretching of the supports of the uterus or forcible insertion of the electrode. The latter should be inserted by touch rather than by sight, and when the fundus is reached it should be withdrawn a trifle to avoid pressure at the apex of the cavity during the passage of the current. The usual frequency of application need not be departed from, and the strength of the current used should be gauged by the results gained at the previous treatment. A judicious rest after the application must be enforced in some cases. The positive pole is generally preferable, owing to its bactericidal properties, at least in high dosage; but if the menstruation be scanty, as in neurotic cases, the negative pole is best.

Such a method of treatment will be found to yield results without a

[1] The writer invariably passes all currents through a controller. See *supra* and "Electricity in the Diseases of Women," by G. Betton Massey, M.D. Philadelphia: The F. A. Davis Co.

parallel in any other remedy. Cases due to puerperal infection, even though of some years' standing, will respond quickly. Gonorrhœal cases are slower, if seen in late stages, particularly if there be extension to the tubes; in these a symptomatic cure will often be marred by the continuance of the leucorrhœa for some time.

The treatment of the second class of cases mentioned—those in which the local metritic trouble is accompanied by reflex disturbances of the general health—requires greater patience, and possibly, also, a more profound experience in the management of chronic deviations of the general health. Here the too-seldom combination of neurological methods with gynæcology is essential, and an effort to leave either element out of the therapeusis will make it ineffective. To the method detailed above should be added such combinations of general electrical treatment, massage, rest, and seclusion as experience dictates; and it may be said that removal from home surroundings is invariably essential.

Selected cases of metritis complicated with salpingitis and oöphoritis need not be denied the benefits of the intra-uterine treatment just mentioned, if it is preceded by a vaginal galvanic course of proper duration and the intra-uterine applications are tentative and made with the elastic electrode, cotton-covered, and inserted with gentleness. The amelioration of the original trouble will often find a quick response in the tubal affection (if non-tubercular), the galvanic drainage of the uterus thus secured resulting in a more or less intermittent drainage of the tubal cavities and tortuosities. The presence of salpingitis should, nevertheless, be accepted as a caution as to frequency and strength of the intra-uterine galvanic applications and an indication for greater reliance on the slower method of vaginal applications. While this should not be forgotten, I have had recent experiences that convince me that these cases need not be universally abandoned to the extreme surgical views of the day. One of the most striking instances of the value of electricity in what appeared to be a genuine pus-tube was that of a lady who was admitted to my sanatorium from Virginia with a history of pelvic trouble since the birth of her only child, thirteen years before. The principal seat of pain was in the left ovarian region. The leucorrhœa was insignificant. Examination disclosed the uterus and appendages prolapsed to the first degree, the uterus being slightly enlarged and retroposed. In the region of the left ovary there was an elastic, fluctuating mass about the size of a duck's egg, the whole being quite tender. Treatment was begun by the vaginal method and continued for some weeks, with a lessening of the tenderness. Intra-uterine treatment was then employed once a week by means of the elastic, cotton-covered electrode inserted but one and a half inches, with a dosage of 30 milliampères negative, the periods being scanty. The following period was freer, peculiar strings of mucus being noted, and examination after it showed the soft mass contracted to the size of the index finger. Under

continued treatment this did not fill up again, and a marked increase in the leucorrhœal discharge was observed. When the patient was discharged the tube was about the size of a lead-pencil, though still easily made out, the uterus was smaller, and the patient's sufferings were relieved. These applications were made under circumstances that permitted complete rest for twenty-four hours afterward, and were but slightly painful. Before treatment the evening temperature generally reached 99° F., becoming normal as improvement set in.

It was evident that this case was one of metro-salpingitis with an imperfectly-encysted pus-tube. That such a tube may be made sufficiently patulous to permit natural drainage is fully in keeping with what we know to follow nasal applications when a rhinitis has extended into contiguous cavities.

HÆMORRHAGIC ENDOMETRITIS.

It may be said that the galvanic current is indicated for the cure of all chronic discharges from the uterus, and that, properly applied, it is by far the best mode of treatment, though but one of a number of reasonably successful remedies now used by gynæcologists for the purpose. When the discharge is hæmorrhagic, either intermenstrual or menorrhagic, it has, however, but one rival at present,—the curette. Compared with curettage in this condition, electricity has the double advantage of greater certainty of action and freedom from risk. Granular, exfoliative, or polypoid forms respond with equal certainty; and even when the *débris* or the polypi are too voluminous to be capable of removal by galvanic drainage and necessitate curettage, the use of the current subsequently is an advantage to prevent return of the condition. The value of the current in stimulating contraction and interstitial absorption also distinguishes it from the mere use of the curette, as these conditions are invariably accompanied by hyperplasia of the substance of the uterus.

The positive pole of the galvanic current is always indicated, though Nunn advises that it be preceded at times by the negative for the purpose of dissolving thickened secretions. The best form of electrode is the carbon-bulb set of Apostoli, made in this country by Flemming (Fig. 5), the largest one capable of being inserted being used, passed gently to the fundus, and a current of 40 to 100 or more milliampères turned on. The electrode is held in this position from two to three minutes; the current is then lessened, and, with the finger in the vagina locating a notch, the electrode is withdrawn until another notch is touched, when the current is again turned on to the same strength and for the same duration. This *sectional cauterization* is repeated until the bulb again impinges on the internal os, the whole of the endometrium being thus brought into contact with a concentrated polar action. Such thorough forms of treatment are not always required, particularly when it is

merely a bleeding tendency rather than a bleeding surface, as in menorrhagia. At such times the covered elastic platinum electrode may be used, and, while causing less irritation, it may be equally effective.

The intermenstrual period must be selected for the applications, as in these chronic cases treatment during the period usually aggravates the flow, and the frequency should be two to four times per month.

METRITIS WITH DISPLACEMENTS AND FLEXIONS.

Fixation.—Metritis, with fixation of the uterus from shortening of one or more ligaments, or from adhesions due to pelvic peritonitis, is often amenable to èlectricity applied by the vaginal method, particularly if iodine in Lugol's solution or potassium iodide is also used by cataphoresis. If the cataphoretic method is employed, the positive pole is essential within the vagina, the electrode shown at Fig. 6 being covered

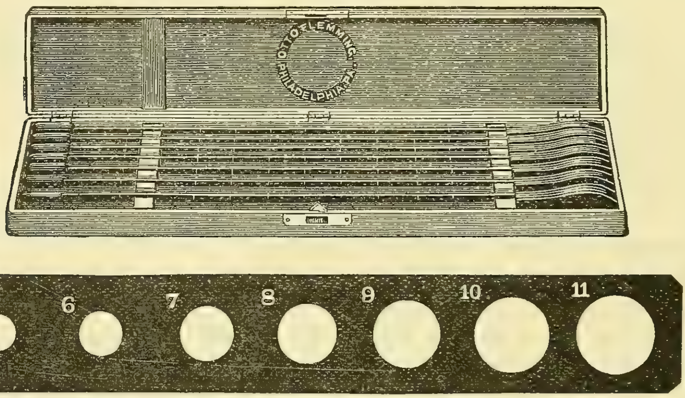

FIG. 5.—APOSTOLI'S CARBON-BULB ELECTRODES.

at its extremity with absorbent cotton, smoothly wound, as with an applicator, and saturated with the solution, the whole being then inserted within the vagina through a Goodell or other bivalve speculum. If no medicament is used the negative is preferable as active pole, being somewhat more sorbefacient. The indifferent pole is a clay pad or equivalent large conducting surface on the abdomen. A current of 40 to 100 milliampères is turned on through the controller and maintained five to eight minutes daily. In some cases it is well to pass a mild secondary current simultaneously through the circuit by means of a combiner. Cellulitic deposits disappear rapidly under this method, the less-organized adhesions give way, and a uterus that has been firmly fixed for years may show increased mobility in a few weeks. A varying amount of fixation is generally found remaining after treatment, somtimes none at all; but unless the adhesions are accompanied by cystic or purulent formations in the tubes and ovaries, the patient will be symptomatically cured, harmless fibrous attachments remaining of no consequence to her.

Mobile Versions and Flexions.—Versions and flexions of a movable uterus that give rise to no symptoms need no treatment. Where suffering is present, it has been the observation of the writer that some form of endometritis or metritis also exists. Intra-uterine negative galvanic treatment will usually be found to remove the symptoms and do much to correct the simple malpositions when conjoined with faradic currents. It is seldom, however, that any material alteration can be made in the shape of flexed uteri, even in cases in which all suffering has been removed. The flexions are doubtless the remains of local inflammations

Fig. 6.—The Massey Vaginal Cotton-Covered Electrode (Uncovered).

of longitudinal muscular fibrils, ending in local atrophies of portions of the uterine substance. It is quite unlikely that anything like obstruction of the canal occurs in the moderate degrees of flexion usually found.

It has been recommended that the faradic current be applied, monopolar, in the bladder in cases of retroflexion, and in the rectum in anteversion, but I have no experience in the matter.

Prolapse; Relaxation.—When a prolapsed uterus is manifestly the seat of hyperplasia, it is essential that the methods given elsewhere for this variety of interstitial fibrosis be employed for the purpose of reducing the bulk of the organ, while the ligamentous supports are also strengthened by primary or coarse-wire secondary induced currents administered by the vaginal bipolar electrode (Fig. 7). The intra-uterine

Fig. 7.—The Apostoli Bipolar Vaginal Electrode as Modified by the Author.

applications are administered under the precautions as to current-strength and duration and frequency noted in the paragraphs on catarrhal metritis, but the vaginal applications should be made daily if practicable. When there is no marked uterine disease or enlargement, and the condition is one of relaxation simply, shown by the existence of rectocele and cystocele, as in many women after the menopause, I have had excellent success from a vaginal cataphoretic method following the bipolar applications. This consists in a diffusion of a saturated solution of tannin in a little glycerin and water, a small quantity only of glycerin being used on account of its tendency to counteract the action of the tannin. The cotton-covered electrode, saturated with this solution, is applied to the vaginal walls as the positive pole and the galvanic current turned

on in the ordinary way. The use of tampons is avoided as tending to further stretch the vaginal walls.

Fibrosis (Hyperplasia) and Fibroid Neoplasms.

The subject of fibroid processes in the uterine tissue has become one of very great importance to the electro-therapeutist since the patient genius of Apostoli demonstrated the value of electricity in these conditions. In spite, however, of the wide-spread acceptance of his views, and the large number of physicians who employ various modifications of his methods, much work yet remains to be done to so popularize the treatment among members of the profession that patients may be placed under it in the early stages of the affection. The studied expectancy that has ruled in the past, among those who shrank from radical operations for benign growths, has resulted in many cases being also denied prompt electrical treatment until the growths have become a burden to the patient, or have resulted in marked deterioration of the health. So great is the indifference thus engendered that few tumors or fibroid processes are diagnosed before being far advanced in growth. Each large tumor has been but a nodule at some time, and, in all but the exceptional few, was capable of being diagnosed by a careful examination at a time when the symptoms were supposed to be due to ulceration, metritis, displacements, dysmenorrhœa, or even ovarian disease. The well-established value of electricity should stimulate the early discovery and prompt treatment of such growths, since early treatment cannot be other than decidedly advantageous.

The etiology of fibroid processes within the uterine parenchyma is still obscure, but enough is known of fibrosis in general to show that it is an hypertrophy of the normal connective-tissue elements, or, in the case of myomas, of the uterine parenchyma itself. According to the classification laid down by Loomis, in his discussion of fibroid processes at the Congress of American Physicians and Surgeons, in Washington, in 1891, these processes are somewhat distinct from those found in ordinary inflammation, though allied to them, and are dependent on a perversion of the nutritive supply to the tissues of the organ, rendering it insufficient to maintain the higher elements, the connective-tissue cells, which maintain a lower nutrition, going on to hyperplasia. Accepting this definition, the disease is essentially an affection of the local trophic processes.

Arising, thus, in a disordered condition of the trophic nerves of the uterus, uterine fibrosis may either be found associated with chronic interstitial metritis, or else simulating this affection by the production of similar symptoms in the early stages of the growth of the buds.

Interstitial fibrosis, or hyperplasia, is not easily distinguished clinically from chronic metritis. The organ is enlarged and hardened. Its muscular tissue has been largely replaced by connective-tissue ele-

ments, and it has become almost a foreign body within the pelvis. The tendency to grow beyond a moderate enlargement of the whole organ is small, and, unlike chronic metritis, it generally gives rise to but slight derangement of the general health. The therapeutic indications are to stimulate the flagging trophic nerves and to promote absorption of the hyperplastic but lowly organized material. Negative galvanic applications to the uterine cavity are usually efficient in causing material reductions in bulk and arresting the degenerative process. Faradic currents are of little or no service, since the muscular tissue is generally wanting. The galvanic applications should vary from 25 to 150 milliampères, according to circumstances and to the size of the organ. Since the endometrium is rarely affected, there is no advantage and no necessity for cauterization of the endometrium; hence it is best to use an elastic electrode well covered with absorbent cotton, attached and moistened as described elsewhere.

When the fibroid process has the shape of *isolated foci of development, surrounded by more or less healthy uterine tissue*, rather than that of a mere interstitial replacement, the process exists which results in the more progressively increasing neoplasms that at times attain enormous proportions. It is said that no nerves have been discovered within the substance of this morbid tissue, yet its avidity for absorbing nutriment from the healthier surrounding tissue is so great that patients often experience marked weakness from the drain upon them. The incipient buds of this form of fibrosis are specially liable to produce symptoms that simulate more common uterine and pelvic disorders, and many cases go through fruitless years of experience with tampons and pessaries, only to discover that the real source of the trouble is an incipient fibroid growth, which should long since have been under treatment.

A certain proportion of these cases, it is true, attain considerable size before giving rise to any symptoms, but the physician should make a special search for nodular enlargement of the uterus whenever confronted with persistent pain, heaviness, and tenderness in the organ itself or in its neighborhood. About 75 per cent. of my cases give a history of having been treated for some form of womb disease for varying periods before the recognition of the tumor; and too often the physician remains equally inactive after its recognition, both from a disinclination to advise surgery and deficient belief in the value of electricity. Early recognition and early treatment of these cases would have secured relief at a time when it was most easily given. Moreover, the early treatment of fibroid growths has the advantage of placing all cases within the list of those amenable to electricity, while delay permits of some becoming unsuitable for it by reason of cystic or other degenerative changes, which appear only after considerable size has been attained.

The too-prevalent attitude of expectancy on the part of the profession is well illustrated by certain cases under my care occurring among

the wives of physicians. Each one of these has been large, the smallest nearly as large as the adult head, and each had been under observation for years. The small tumors are rarely seen by the specialist unless first diagnosed by himself; several have been discovered in my own practice, in cases in which I had presumed that simple metritis existed, the shrinkage of the engorged uterine tissue making the nodule appreciable to the touch.

But little change has been made in the methods advocated by Apostoli in the treatment of fibroid tumors. An impression first gained currency in this country that the method by electro-puncture was most effective, but this was clearly a mistake, and has given way to a conviction among specialists that the original method of intra-uterine application is preferable in all cases in which the electrode can be inserted within the cavity. In the rare cases where this is impossible, and where a nodule of the growth projects downward in such manner as to be immediately beneath the vaginal wall in the posterior *cul-de-sac*, *vaginal puncture* may be practiced under strict antisepsis. My own vaginal punctures have been invariably negative in this situation, and by the buried method; that is, the needle was inserted sufficiently far to have its bare tip buried within the morbid tissue and the healthy intervening structures protected from current-action by the fused hard-rubber coating that covered the needle to within a centimetre of its end. Such punctures always have the disadvantage of being made within a cavity in which surgical cleanliness is subsequently difficult of maintenance, even when the vagina is packed with antiseptic gauze, and are, therefore, always employed by the writer with reluctance. This disadvantage does not accompany *abdominal puncture*, which I have employed in a number of large growths lying entirely within the abdomen and inaccessible to safe treatment from below. In each of these cases the growth lay immediately beneath the abdominal wall, and was sufficiently large and prominent to render it impossible to injure any abdominal viscera when it was clearly ascertained that no intestines were held in front by morbid adhesions. The needles employed are the straight Hagedorn surgical needles, about two inches long, and insulated by fused hard rubber to near their tips. Two or three of these, thoroughly asepticized and attached to the negative binding-post by fine copper wires, are thrust directly into the most prominent portions of the growth until their ends are buried in the tumor. This may be done painlessly if the skin at each point of puncture is lightly frozen by the rhigolene spray. A large clay pad attached to the positive pole having previously been placed beneath the patient's back, supplemented by others on the thighs if necessary, the current is turned on until 100 to 250 milliampères are in circuit.

This method is really less painful than the intra-uterine applications, but it shares with vaginal puncture the disadvantage of maintaining an electric density too far away from the nutritive sources of the growth,

for it should not be forgotten that the applications are most effective when made nearest the hilum, or point at which the tumor receives its nourishment from the uterine tissue. The method has, however, yielded reasonable results, and in a large number of punctures made by the writer no bad results of any kind have been encountered.

In the writer's experience seven tumors have been so reduced in size as to leave mere irregularities on the surface of the uterus. One of these was mainly subperitoneal and was treated by vaginal puncture, but the remainder were all intra-mural, varying in dimensions from a hen's egg to an adult head, and were treated by the intra-uterine method. All hard, intra-mural tumors subjected to treatment of sufficient duration have been symptomatically cured and, so far as known, arrested in growth, more or less reduction in size being almost invariable.

The impression that a destructive electrolysis is necessary in the treatment of fibrosis by electricity is erroneous. We often get the best results in cases in which moderate currents only are used (30 to 80 milliampères), though a greater dosage is usually necessary, probably because a certain density is requisite at the active pole in order that the trophic processes within the growth may be properly affected. The most reasonable explanation of the mode of action of electricity on these neoplasms is that it acts as an alterative to the morbid processes, arresting the cell metamorphosis in which the fibrosis arises, and stimulating the absorbents to a quickened removal of the products of the arrested process.

Contra-indications.—Tumors that have undergone cystic or purulent degeneration, that are surrounded by a purulent process, or that are removed from direct treatment by a subperitoneal situation, should not be treated by electricity.

Carcinoma of the Cervix.

A limited experience in the treatment of cervical cancer with electricity has convinced me that destructive current-strengths have a distinct field of usefulness in this sad condition. The method employed is probably different from that advocated by Inglis Parsons, who deserves special credit as a pioneer in the recent advances in the electrical treatment of cancer, and its description here may be of interest. The method varies as the cancerous growth consists of a flat, ulcerated cancer, or of a cauliflower or other tumerous projection.

1. *Superficial Cancerous Erosion of Cervix.*—The patient being placed in Sims's position in a good light, and with a negative clay-pad electrode held against the abdomen, the cervix is brought into view and the positive electrode brought into contact with the cavity. A current of from 100 to 250 milliampères is now gradually turned on at the controller and maintained from five to ten minutes. The current is now turned off in an equally gradual manner, and the cavity examined before

repeating the procedure in a possibly different portion of the cavity. The active electrode should be of carbon or other non-corrosive material, and may be most conveniently fashioned from an electric-light carbon with rounded end, insulated throughout its length by a piece of rubber tubing except at the end inserted within the morbid excavation. The use of this cheap and handy material permits the restriction of an electrode to each case, to be destroyed after the termination of the treatment of that case.

High currents may be employed in this manner with but little pain, since the benumbing effect of the positive pole is easily apparent. The fulgurating, neuralgic pains which usually attend these cases are, in fact, largely controlled and subdued by the applications, which quickly stop hæmorrhages, improve the nature of the discharges, and bring away portions of the growth in a crumbly condition. Undertaken when the disease is strictly local and confined to the cervix, there is every reason to hope that it will be ultimately curative. In hopeless cases it is a

FIG. 8.—THE MASSEY HIGH-CURRENT ELECTROLYSIS INSTRUMENT, FOR MALIGNANT GROWTHS OF UTERUS.

valuable palliative. The strength of the current must be great, though proportional to the gravity of the case, and may be applied frequently.

Some writers have used the added corrosive effect of the oxychloride of zinc, which may be developed *in situ* in a nascent condition by the employment of surface of bare zinc as the active, positive pole, but I have myself preferred to employ the simple polar action of the positive pole under a conviction that this polar action in concentrated form will destroy the life-action of the cancer-cells in its immediate neighborhood. The use of the monopolar method has also the possible advantage over other caustic agencies of permitting us to apply a dense interpolar current throughout the ramifications of the cancerous tissue. Soft cancerous growths are unquestionably better conductors than the surrounding healthy tissue; hence the deeper offshoots of the growth will receive the bulk of the current in its passage between the poles. That cancerous tissue possesses less resisting power than healthy tissue to the histologically-lethal action of strong currents is a reasonable conclusion, based on the known lack of vitality in the cells.

2. *Cauliflower Excrescences and Encephaloid Growths.*—When the cervical cancer is in the form of a solid or semi-solid tumor, it may be destroyed by the immediate electrolytic action of currents of from 400 to 800 milliampères, confined directly to the growth by the double bipolar needle electrode shown in Fig. 8. This is thrust into the growth with

the patient in the Sims position (an insulated Sims speculum being preferable in both this and the preceding procedure, or care being observed not to bring the electrode into contact with a bare metal instrument) and the current turned on as before. Considerable heat is developed between the prongs of the instrument during the passage of high currents. If the growth is not very firm it is soon reduced to a brown liquid in this situation, without loss of blood. This saving of blood is a distinct advantage of the method over the curette or écraseur, as blood-loss is serious in these cases. Secondary hæmorrhage is prevented by the firmly-coagulated edges left, which separate later, after the formation of lines of demarkation or by liquefaction.

When the tumor has thus been disposed of, the resultant cavity should be treated by the monopolar method employed in the ulcerated variety.

THE ELECTRICAL TREATMENT OF FIBROID TUMORS OF THE UTERUS.

By DR. GRAND and DR. FAMARQUE,
ASSISTANTS AT THE CLINIC OF
DR. APOSTOLI.

Introductory and Historical.

We will consider very briefly the history of the treatment of fibroid tumors of the uterus by electricity. We will cite only the labors of Cheron, Tripier, Cimselli, Brocbit, Onimus, and Martin, who successively from 1861 to 1880 employed different methods of application of electricity to the treatment of fibroid tumors of the uterus. The rheophores were placed either exteriorly upon the abdomen or lumbar regions, in the vagina or against the cervix. The intensities employed (always low) were insufficient, and gave only results proportionate to the number of cells utilized. Cutter, in America, and his imitators, Semeleder, Kimball, Gaillard Thomas, and others, implanted in the body of the tumor, through the abdominal walls, metallic electrodes in the form of sharp-pointed rods, which also served to attack the tumor through the vagina if accessible only from this direction. The mortality was high, and this method has remained in the experimented stage.

It was in 1882, in the hands of Dr. Apostoli, that the electrical treatment of fibroid tumors of the uterus really became methodical, thanks to the utilization of the galvanometer of intensity, which rendered possible the systematic applications of currents of electricity never before employed. His method, now classical in France, as well as in Europe and America, comprises not only the treatment of fibroid tumors, but also embraces to-day the whole pathology of the pelvic organs in women; and electricity in his hands is applied not only to the treatment of affections of the uterus and appendages, but serves in the happiest manner to determine the diagnosis (so often doubtful) in inflammatory and suppurating lesions of the uterine periphery.

An essentially conservative method, it brings to the aid of the surgeon most precious assistance in doubtful cases, by determining, with the rigorous exactitude of an experiment in physics, the indications and opportunity for radical intervention. The electrical method of treatment applied by Dr. Apostoli since 1892, to the cure of fibroid tumors of the uterus, differs from other treatments in several respects:—

From an Operative Stand-point.—1. The applications are always intra-uterine and exceptionally parenchymatous or vaginal, of the continuous current, without interruption and without reversing the poles.

2. The employment—wherever possible, or when it is not contra-indicated—of high intensities, but always measured by the true uterine susceptibility.

From a clinical stand-point, by anatomical and symptomatic results most constant, rapid, and durable.

The applications of the continuous current comprise galvano-cauterization and galvano-puncture, positive or negative. Each of these applications has its field and its indications, which will be described; but they all have this in common: the current is localized; its dissemination and

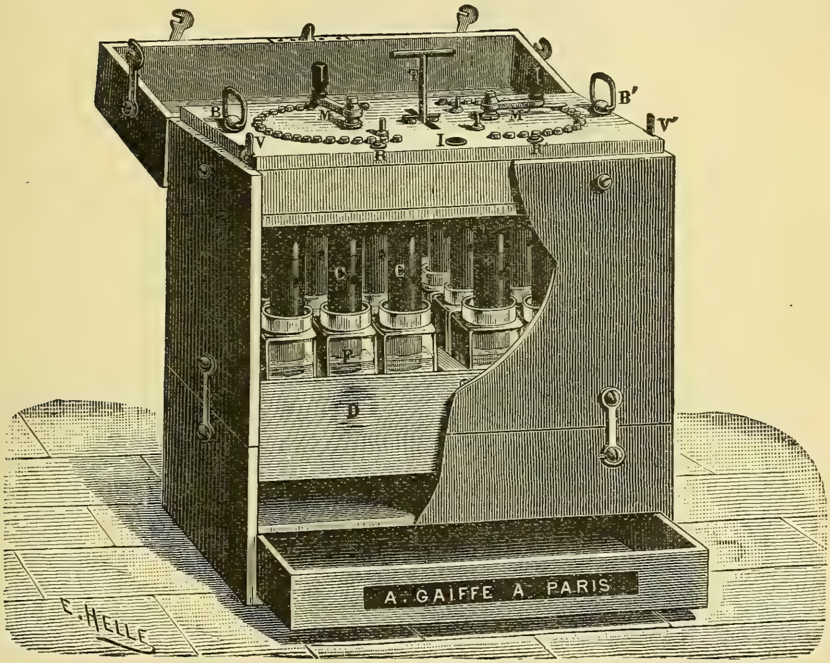

FIG. 1.

loss is prevented, by which its action is assured and augmented. By high intensities is meant above 50 milliampères, measured by a good galvanometer. These intensities render impracticable the interruption or reversing of the current; but clinical observations demonstrate that the results are more constant, rapid, and durable as the intensities are elevated. This treatment, supported by theoretical reasons which I need only mention, and justified by clinical results which will occupy us above all, has justly merited the title of a method which we have given it. We will study, in succession, the apparatus required, the contra-indications, the method of operating, the operative and post-operative reactions, the limits of intensities, the results, and the causes of non-success.

Apparatus Required.

The apparatus required to practice the method of Dr. Apostoli may be divided into two parts,—essentials and accessories. The essential parts comprise a continuous-current battery, a galvanometer, exciters, electrodes, and rheophores. The accessory parts are an interrupted-current battery, with vaginal and intra-uterine bipôlar sounds.

The continuous-current battery, whatever its composition, should be able to give 300 milliampères of intensity, which is sometimes, though rarely, attained. The battery employed at the clinic of Dr. Apostoli is composed of 36 Leclanché cells, modified by Gaiffe; it is not portable. A portable battery is also required to carry to the house of the patient.

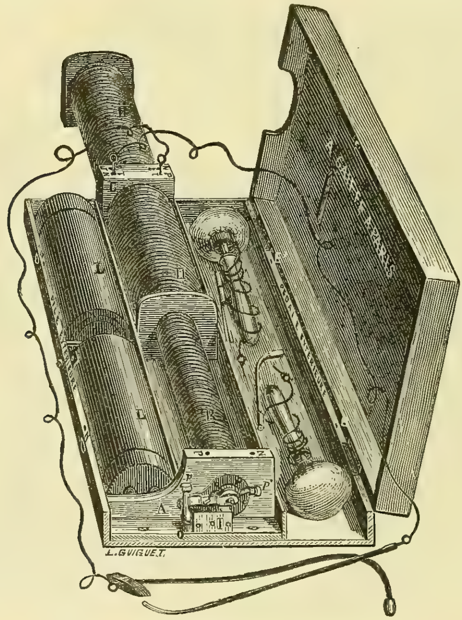

Fig. 2.—Portable Faradic Battery.

The one constructed by Gaiffe is composed of 24 cells, giving 200 milliampères (Fig. 1). A good galvanometer, graduated to 300 milliampères, is required. The last model of Gaiffe is aperiodic, and works either in the horizontal or vertical position (Fig. 3).

The exciters comprise a metallic monopolar sound, monopolar sounds of carbon for galvanic cauterization, and trocars for galvano-puncture: 1. The metallic monopolar sound used by Dr. Apostoli is a straight platinum stem sliding in a hollow wooden handle, capable of being fixed by a screw at any desired length (Fig. 4). The sound is made of platinum because, of all the metals, this is the only one not attacked by the salts of mercury, and the only one except gold not attacked by the acids of the positive pole,—a double quality, by which all loss of current

is prevented and perfect antisepsis is possible. It is straight and rigid; hence capable, when necessary, of replacing the uterus and pressing out folds of mucous membrane. Before introducing it is covered with a sheath of celluloid, glass, or hard rubber for preserving the vagina from the action of the current. It is important in practice that the insulating sheath should glide smoothly over the sound, so that when pushed forward against the cervix it will not be done with a jerky movement, which would

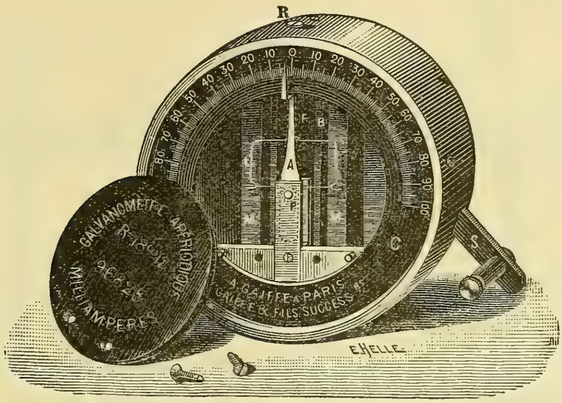

FIG. 3.

cause useless pain when the cervix and uterus are in an irritable state. 2. The carbon monopolar sounds consist of a stem of metal insulated by a layer of gutta-percha, terminating at one end in a cylinder of carbon (Fig. 5). This stem, like the platinum sound, and for the same reason, is straight and rigid, of thirty-five centimetres in length, and every two and one-half centimetres it is marked by a circular trench, the use of which will be explained in describing the method of making the galvano-cauterizations (Fig. 6). In all the sounds numbered from 1 to 12 which Dr. Apostoli has had made, and which suffice for the requirements of practice, the

FIG. 4.

carbon extremities have a uniform length of two and one-half centimetres, and the diameters increase with the numbers up to twenty millimetres (Fig. 7). 3. The last trocar of Dr. Apostoli for galvano-puncture is in the form of a straight metallic stem terminating at one end in a gold point of triangular shape; the length of the stem is thirty-five centimetres and is insulated with gutta-percha. The stem is fixed in the handle of the platinum sound. With this trocar deeper punctures can be made without sloughs and with less pain (Fig. 8).

The electrode designed to be applied upon the abdomen of the patient and to receive upon its superior surface the metallic plaque which closes the circuit is prepared by modeling sculptors' clay in a rectangular form, of wood or iron, a centimetre and a half in height, and the other dimensions thirty by eighteen centimetres; the bottom is covered

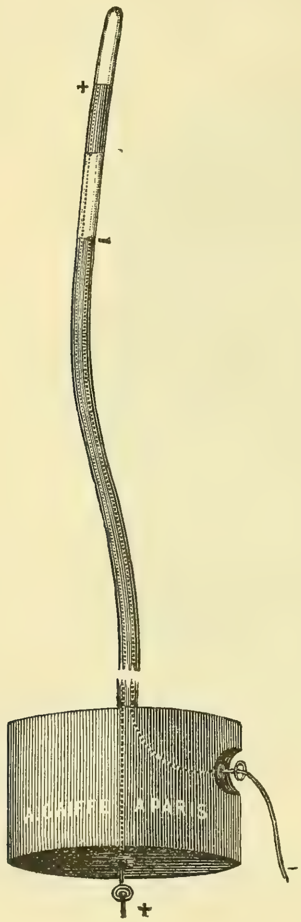

FIG. 5.

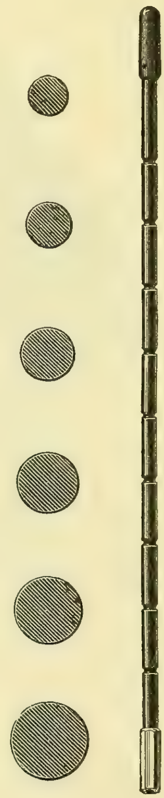

FIG. 6.

by a piece of muslin large enough to fold over the upper surface and cover it entirely. It must contain no foreign body, which is assured by passing over its surface the end of the finger. It must be neither too soft nor too hard. The same clay may be used indefinitely; the same electrode can be employed several times, upon condition that it is kept, between the *séance*, enveloped in some impermeable material. At the moment of using it the surface may be moistened if a little dry, but it should not be warmed, for heat makes it hard and scaly. If it have the

inconvenience of soiling objects and of being cold, this electrode owes to its plasticity the advantage of molding itself and adhering intimately to the skin, and, in consequence, higher intensities can be attained, without causing pain, than by any other. With a clay electrode well prepared, intensities in the vicinity of 200 milliampères scarcely cause the patient more than a very supportable sensation of heat and a slight redness of the skin, which quickly disappears.

The rheophores connecting the battery with the sounds and the metallic plaque are formed of flexible copper wires, covered with silk or

FIG. 7.

caoutchouc, furnished at each end with a metallic tip. In consequence of the twisting and pulling they are subjected to, these wires finally break, usually at their points of attachment. The break, being masked by the silk or caoutchouc covering, may not be perceived; hence it is necessary to verify or change them frequently, to prevent an interruption of the current during a *séance.*

The apparatus already described is sufficient to practice the method; that is, to make the galvano-cauterization and galvano-puncture with intensities as high as 300 milliampères. But there are cases in which the introduction of the sound is painful and the employment of high intensities impossible, owing to the local or general nervous condition of the

FIG. 8.

patient. In order to accomplish the operation with less pain, or even to render it possible, an immediate uterine preparation is required. It is for this local preparation and for local and general nervous sedation that vaginal or intra-uterine faradization with the interrupted-current apparatus and bipolar sounds (vaginal, Fig. 6; intra-uterine, Fig. 5) is employed. In these cases the fine-wire coil only of apparatus, or of that of Tripier, is employed. High-tension faradization, as we shall see later, is also a test employed when it is a question of fixing a doubtful diagnosis.

To the apparatus already described there has been added quite recently the sinusoidal-current apparatus invented by d'Arsonval. Dr. Apostoli has lately reported, at the Congress at Brussels, the first clinical experiments made with it.

Contra-indications of the Method—Conditions of Success.

Fibroid complicated with an acute uterine or peri-uterine lesion, or with a chronic suppurating peri-uterine lesion, cystic or fibro-cystic tumors of the ovaries or tubes, soft fibroids or fibroids complicated with ascites, contra-indicate the method either absolutely or relatively.

An ante-uterine or peri-uterine lesion or a chronic suppurating peri-uterine lesion contra-indicates it absolutely and always. The continuous current can only revivify or spread the first, and cause a renewal of the process in the second if employed at the commencement with high intensities. With low intensities the method is not injurious to the accompanying fibro-cystic tumor of the ovaries or tubes, but is without a favorable influence upon the fibroid; if favorable as regards the latter, it is of no benefit to the former, and may even be the reverse, particularly if it should be the seat of an unrecognized inflammation. The majority of fibroids complicated with ascites are not influenced by the method; it is also without effect upon soft gelatinous fibroids where nearly all the muscular tissue has disappeared.

Other complications,—a chronic non-suppurating lesion of the appendages, for example,—without absolutely contra-indicating the method, contra-indicate the employment of high intensities, and consequently the results are retarded or indefinitely postponed. But, in face of all the complications except an acute uterine or peri-uterine lesion, it is not necessary to renounce the method at once; on the contrary, it must be attempted and tested.

Employed according to the operative method and rules which are well indicated, if it fail, the patient will have incurred no danger, and the diagnosis so often difficult will be confirmed, or established, and the treatment decided. In certain cases it has given favorable results, contrary to all expectations; thus, in some cases of fibroid with ascites, the water has been absorbed and the symptomatic condition ameliorated. Very difficult is the diagnosis of an inflamed fibro-cystic tumor of the appendages; very difficult also that of an old chronic peri-uterine lesion, which betrays itself by no precise anatomical or symptomatic evidence; and when the early history is forgotten or vaguely remembered by the patient, *a fortiori* it is difficult to determine if the lesion contain pus, electricity, under the two forms of the faradic and continuous current, sheds precious light upon the diagnosis by means of the reactions which accompany and follow the applications, and thus sometimes serves as a remedy and as a beacon.

Given a patient with a fibroid tumor, where a lesion of the appendages is suspected because she suffers in that locality, spontaneously or upon pressure, submit her to a vaginal or intra-uterine faradization; if the pain disappear or is much attenuated by the *séance*, it is not due to a lesion of the appendages, but is simply nervous. We will cite a typical example

among many of pain whose true nature was revealed by faradization. The case occurred at the clinic of Dr. Apostoli, and the diagnosis was verified by several physicians. A patient cured symptomatically of a fibroid tumor by the electric treatment was attacked brusquely in a small area of the left iliac fossa by a pain so violent that a slight touch brought forth cries of pain. She was brought to the clinic with the diagnosis circumscribed peritonitis. At once Dr. Apostoli made an intra-uterine faradic application, which was followed in ten or fifteen minutes by the complete disappearance of the pain. The part which could not be touched without causing the patient to cry out remained insensible to pressure, however deeply applied. Pains attributed to an acute affection of the appendages or peritoneum have occasioned a resort to bleeding, upon the supposition of their being of inflammatory origin, when, and not infrequently as in the above case, they were simply ovarian pains.

But if after one or several faradizations the pain is not attenuated, or but slightly so, and for a short time, it is certain that it is due to an inflammation of the appendages. Galvano-cauterization and the galvano-puncture, also, applied according to certain rules as regards intensities, aid the diagnosis and constitute a second, yet more certain test. If a patient with a doubtful fibroid react neither during nor after the *séance* to 50 or 60 milliampères,—that is to say, if she do not suffer, or do not suffer more than before; if the passage of the current is shown only by uterine colic or lumbar pains, quickly disappearing; if her general or local symptomatic condition is not aggravated; above all, if there is no febrile movement and she experiences some amelioration,—it can be affirmed that the fibroid is without complications. But if the symptomatic state suffer a recrudescence which lasts and is accompanied by fever, the fibroid is complicated with some uterine or peri-uterine inflammation. The degree of this inflammation, its simple chronicity or its suppuration, is revealed by the intensity of the reaction that accompanies or follows the experimental galvano-cauterization or galvano-puncture.

For greater certainty, let the two tests be consulted and let one control the other, their response will confirm the diagnosis and withdraw from the therapeutics an indecision prejudicial to the patient. We need call attention to the statement that the existence of a simple chronic peri-uterine lesion does not contra-indicate the treatment as a whole. It contra-indicates high intensities only. As it may happen that the fibroid only requires intensities which favorably influence some chronic peri-uterine lesions (intensities ranging from 30 to 60 milliampères), the treatment should be given a trial in these cases. The amelioration will doubtless be slow, but, if it come at all, we have at one stroke obtained a relative end of the ovaro-salpingitis, for example, as well as the fibroid, and saved the patient from surgical intervention.

People who are naturally impatient find this course very long and tedious; they prefer a resort to more expeditious resources, such as hys-

terotomy and castration. But, beyond the fact that patients in general have little taste for such remedies, they honor the method of Dr. Apostoli, conservative above all, which, without risking their lives, preserves to them the right of maternity.

We are firmly of the opinion that this means of making a diagnosis, tested as it has been many times, and its accuracy confirmed by operations performed afterward, as recently reported by Dr. Apostoli at the Gynæcological Congress at Brussels, and to the Société Française d'Electro-Thérapie, should put a check upon the rashness of surgery, which, simply to verify a doubtful diagnosis, does not shrink from an exploratory laparotomy.

En résumé.—We may say that there exists two kinds of contra-indications: the one excludes the method *en bloc;* the other excludes only high intensities. Finally, the diagnosis, when doubtful, may be established by two observations: 1. The absence of reactions with all intensities. 2. The reaction which follows an experimental treatment.

The three varieties of fibroids—interstitial, subperitoneal, and submucous—isolated or associated with chronic uterine or peri-uterine complications, except a suppurating lesion, are, in different degrees, amenable to the method of Dr. Apostoli. They are, at whatever the age of the patient, the symptomatology,—hæmorrhage, pain, leucorrhœa, dysmenorrhœa, phenomena of compression,—be the symptomatology simple or complex, or whatever may be the gravity of the local or general condition.

Many are the patients—and the clinic of Dr. Apostoli could furnish a number of examples—also, who, after having tried several kinds of treatment without success, after finding themselves refused the operation they solicited, on account of the local or general condition,—profound cachexia, fixation of the uterus, adhesions, etc.,—and would from that moment hasten to an early death-hour, owed to this method the continuation of a supportable existence.

Have we not the right to declare that such might have been the fate of many patients operated upon without having been submitted to the conservative method, and who have died in consequence of the surgical intervention? The success of the method depends upon some essential conditions. The first of these conditions is an exact diagnosis of the fibroid and of the complications that accompany it. The method fails most frequently when applied to a tumor not a fibroid,—a malignant tumor, for example. It fails also if the complications existing with the fibroid are unrecognized, and, worse still, the patient may be subjected to some danger if the established rules are violated. The sound condition of success is to respect and observe the rules of operative *procedure* and *tolerance.* Not to appreciate or to violate them is to certainly encounter checks in some cases and accidents in others. Rigid asepsis and antisepsis of the patient, instruments, and operator constitute the third condition of success. Each one may, no doubt, follow the antiseptic

method of his choice, provided he realizes the end sought for, which is the security of the patient. But we will describe with some detail the practice of the clinic, because its value is demonstrated by the absence of an accident due to septicæmia. There has been more than three thousand patients treated there or examined, in many instances by several physicians in succession. These patients were of a social grade that did not permit them to take always the necessary time for their vaginal toilet, nor to perform it with the care recommended. The practice is as follows:—

Every patient *should* take at her home, morning and evening, with an apparatus giving a constant stream and furnished with a glass tube, a vaginal injection containing fluoric acid in many cases, or the sublimate when there is a specific vaginitis or urethritis. At the clinic a large and carefully-administered injection containing the sublimate is practiced upon such patients before and after every *séance*. The tube should penetrate as far as the cervix, and the finger should carefully explore the *culs-de-sac* and present the folds of mucous membrane. The outflow of fluid may be aided by depressing the fourchette.

Besides the usual precautions as regards cleanliness, the careful washing of the hands, not omitting the nails, the operator bathes his hands in a sublimate solution, and when about to practice the touch he dips his finger in a sublimate solution or in vaselin containing chloroform. Before each galvano-puncture or galvano-cauterization the sound is held in the flame of a lamp and then plunged into a bath containing fluoric acid. At the moment of introduction it is dipped into a saturated solution of iodoform in ether or alcohol,[1] and when withdrawn is plunged into a sublimate bath. The trocar, the insulating sheath, and the carbon sounds are boiled and kept, before use, the first in a bath of phenic acid and the others in one of phenic acid or of the sublimate.

Before studying the operative methods we will recall and insist upon this important point, too often neglected or forgotten, that we must not ask or expect from the electric treatment that which it does not nor can not accomplish,—for example, cause the disappearance of very large tumors, produce parallel anatomical and symptomatic results, ameliorate or definitely cure in a few days symptomatic conditions which have existed for years, and which have resisted a variety of medications. It would seem idle to insist upon this if some minds—and we have encountered such and undeceived them—did not appear to expect from the treatment, as the most natural thing in the world, *volatilization*—if we may coin the word—of all fibroid tumors, without distinction, great and small. The method does not perform miracles; and we ought not to be more exacting than the patients, who consider themselves cured, although they still have the tumor, when the symptomatic state has disappeared for which they sought treatment and which caused their suffering.

[1] This solution requires to be renewed as soon as the iodoform penetrates, in order that it may not be irritating to the mucous membrane of the vagina and uterus.

There is not, nor can there be always, a parallelism between the anatomical and the symptomatic results, for we see at the clinic fibroids presenting such peculiarities as these: A serious symptomatic state with a small tumor, and derangements of little moment with a large one. It is also necessary to guard one's self and the patient against a double mistake,—an excessive enthusiasm the result of a rapid symptomatic amelioration, and a discouragement without bounds caused by a sudden aggravation of the disease at the supreme moment of triumph of the long delay of the expected benefit.

If a single *séance* is *sometimes* followed by a symptomatic amelioration, general or partial, *often* after the first few applications the condition remains stationary; often some units of the group—ordinarily the hæmorrhage—undergo a recrudescence, and in the greater number of cases it is only after many *séances* that improvement is clearly outlined and, becoming more and more marked, ends in a definite cure, in spite of the relapses which occur. Sometimes, even, it becomes necessary to suspend the treatment for some time.

Operative Methods—Galvano-cauterization; Galvano-puncture; Faradization.

In order not to repeat to satiety certain details which it is only necessary to mention once, we will enunciate in an aphoristic form those common to both galvano-cauterization and galvano-puncture. The patient, having removed sufficient clothing to facilitate the operation, assumes the obstetrical position in the bed or chair, the muscles completely relaxed, the buttocks well advanced and extending beyond the edge. This position permits the patient to breathe at ease, and affords the operator the necessary facility. Put the galvanometer in the circuit and verify the battery and cords. Assure yourself that the clay electrode contains no foreign substance by passing the pulp of the finger over the surface. If there is any lesion of the epidermis upon the parts to which the electrode is to be applied, cover it with collodion or paper, in order to keep the current from passing through it, thus saving the patient considerable pain or an eschar slow to heal, and which may leave indelible traces. Warning the patient of the coldness of the electrode, apply it gently to the abdomen in such a manner as to cover the tumor, but not to touch the pubes or thighs. The electrode being covered with a folded napkin, the patient applies the palms of both hands to it and makes quite uniform pressure, the augmentation of the surface minimizing the resistance of the current. Always apply the electrode before using the sound or making the puncture with the trocar, as a sudden movement of the patient might cause an injury to the uterus. Let each galvano-cauterization or galvano-puncture be preceded and followed by a vaginal injection. The operative method is the same if the galvano-cauterization or

galvano-puncture is positive or negative, but as the positive pole is less painful it should always be employed on the first occasion if the negative is to be used subsequently.

GALVANO-CAUTERIZATION WITH THE PLATINUM SOUND.

The sterilized platinum sound, armed with its insulating sheath and fixed solidly in its handle, is conducted upon the index finger as far as the external orifice to the canal, and then gently pushed to the bottom of the uterine cavity. The complete introduction of the sound is sometimes difficult and often painful. A displacement of the uterus, an accidental or congenital atresia, a sinuous canal, or fold of the mucous membrane may arrest the instrument, and the same cavity which to-day permitted its passage with ease completely and without pain may to-morrow present the opposite conditions, due to congestion, or spasm, an increase of nervousness, or the approach or termination of the menses.

In order to avoid or diminish, particularly at the first *séance*, the pain and discomfort, which might set the patient's mind against the method, the operator will employ the greatest gentleness and deliberation in the delicate operation of introducing the sound. He will never be aggressive, but wait for the spasm to subside, to retreat at one instant, to advance with more success the next, and finally, if the introduction is incomplete, he will not push, but make the galvano-cauterization at the depth attained. Such is the line of conduct always to be followed.

In cases of hysteria or neuralgia of the cervix, the introduction of the sound is always painful. We recall, among other remarkable examples, a patient of the clinic, with whom, even during a slight examination, the contact of a sound or a tampon of cotton barely touching the cervix brought cries of distress. In another patient treated by one of us every attempt to pass the sound caused an attack of hysteria of several hours' duration, and it was only during the attack and on account of it, when the spasm relaxed, that the operation could be effected. These cases require such expedients as immediate faradization—vaginal or intra-uterine—with the fine-wire coil, and, without the domain of electricity, the administration of the salts of morphia or other anæsthetics.

Dr. Apostoli always introduces the sound without using the speculum.[1] Many times its introduction is painful, often a hindrance, and even sometimes impossible to accomplish,—for example, when the cervix is high up or behind the pubes, when there has been resorption of the cervix, or when the genu-pectoral position is required. When the sound is introduced as far as possible, the insulating sheath is pushed forward until it is in contact with the cervix. The pain occasioned by the sound should be allowed to subside before the current is turned on, in order that the patient may not attribute to this part of the operation the dis-

[1] He recognizes that sometimes a more-perfect asepsis can be obtained by using the speculum, as contact with the vagina is avoided when the sound is introduced.

comfort arising from the passage of the current. Re-assure the patient and promise that the current shall cease upon the first complaint or sign of distress.

The sound being held in one hand, the other turns the switch slowly forward from one button to another, at the same time observing the galvanometer and the face of the patient. At the first complaint or sign of distress seen reflected in the patient's face, cease to increase the current and, if needful, retrograde. When the discomfort has passed or attenuated, begin again to advance the switch with the same caution, until the galvanometer works 40, 50, or 60 milliampères. Although well supported, if likely that the fibroid is a simple one, without complications, still these intensities should not be surpassed at the first *séance*, for an unrecognized peri-uterine lesion may exist and react at the moment, the night following, or the next day. After five minutes the switch is slowly turned back to zero and the sound is withdrawn.

The patient is at once recommended to remain quiet, seated or lying down, for two hours, and, upon returning home, to abstain from sexual intercourse, to avoid fatigue, and to take, night and morning, an antiseptic vaginal injection. These recommendations should be insisted upon and observed with scrupulous care.

Frequently very soon or during the following night there is some uterine colic, accompanied by a sanguineous or leucorrhœic discharge, which, if before present, is increased. This should be told the patient, that she may not be surprised or alarmed. She is also asked to observe and note anything she may experience.

GALVANO-CAUTERIZATION WITH THE CARBON SOUNDS.

A carbon sound is selected corresponding in diameter to the size of the uterine cavity. It is introduced by a corkscrew movement to the bottom of the uterine cavity. The current is turned on for three minutes, after which the sound is withdrawn, for a distance equal to the interval, between two trenches on the stem. After three minutes this is again repeated, and so on until the whole interior surface has been cauterized. For the rest of the operation the same rules are followed as when the platinum sound is used. During the *séance* the observation of Dr. Apostoli, that the sensibility of the mucous membrane increases from the bottom of the uterus to the cervix, can be verified.

GALVANO-PUNCTURE.

The galvano-puncture, whether parenchymatous or vaginal, should be made at the most prominent part of the tumor, avoiding with the greatest care the bladder, the rectum, and large blood-vessels. The finger will carefully explore the region to detect arterial pulsation; catheters will be used, where there is the slightest doubt, to locate precisely the situation of the bladder. We have seen cases where, without this

precaution, it would have been transfixed in the portion covering the tumor.

The point for operation having been carefully selected, with one hand the insulating sheath is held exactly upon it, and with the other the trocar is pushed through it and made to penetrate the tumor. Preliminary to the operation the trocar is fixed in the handle so that the point projects beyond the insulating sheath a centimetre, a centimetre and a half, or for the distance it is intended the trocar shall penetrate. The penetration of the tumor by the trocar is the painful moment, and faradization on the part or an injection of morphia may be used to make it less so. A very timid patient may take an anæsthetic if several cauterizations or punctures, without operative or post-operative reactions, have shown the absence of peri-uterine lesions.

If a large vessel is accidentally wounded, hæmatosis may be produced with the speculum. The remainder of the operative procedure is the same as with galvano-cauterization, save that, for more perfect antisepsis, the part may be covered with iodoform gauze, to be withdrawn by the patient or physician the next day or the one following it, and the repose of two hours should be even more strongly insisted upon than after the other operation. The incidents following either operation are very simple when there are no peri-uterine complications, being limited to some uterine colic and sanguineous or leucorrhœic discharge.

Farther along we will describe the operative method in vaginal and intra-uterine faradization, and at the same time explain the indications of the employment.

Operative and Post-operative Reactions.

We have described the operative methods and the events following a first *séance* of galvano-cauterization or galvano-puncture as they occur when the diagnosis is exact, when there are no inflammatory or nervous complications, and when the operator has himself followed—and obliged the patient to do so—the route traced by the author of the method. In view, first of all, of operative and post-operative reactions, and in order not to injure the prospects of the treatment with the patient by exciting her fear and repugnance, the first *séance* should be conducted with the care and forethought necessary to prevent all suffering.

The subsequent operations should be made in the image of the first, for there should not and can not be any difference except in the intensities employed. But there are deviations from the ideal, or what we may call the classic, *séance*. By the side of the great class of patients who manifest no reactions during or after the application, no aggravation of the symptomatic or general condition before movement, who are indifferent to the passage of the current or experience only some uterine colic or lumbar pain quick to disappear, there is quite a numerous class

of subjects who, during or after a *séance*, present reactions which are due, in order of frequency, to a nervous condition, an imperfect diagnosis, and operative faults. These reactions should be studied for their own importance, and for the indications they afford as regards the diagnosis, the prognosis, and the treatment. The best division we can make of these reactions is into *negligible* and *non-negligible*, and we will endeavor to clearly establish the symptoms by which they can be recognized and differentiated.

The *negligible* reactions, operative and post-operative, cannot be referred to any precise type, for they vary infinitely in character, duration, and intensity. The nervous reactions assume the most diverse forms,—laughing, crying, chilliness, chattering of the teeth, shrieks, trembling, convulsions, etc., even semi-syncope and semi-unconsciousness, which render her insensible to all appeals. These phenomena are not due to hypnotic suggestion, but to the passage of the current, for we have frequently proved the absence of the former by arresting the current, affirming to the patient that it was still passing. In some cases these reactions begin with the passage of the current and terminate at the close of the *séance*. In other cases they persist for a little time, during the evening or the night following, most frequently attenuated, sometimes intensified, but always followed by a certain amount of improvement. Some reactions follow the oscillations of the current, augmenting and diminishing with the intensity; the former burst out with any intensity, but these appear upon a change from one intensity to another. However impressive they may be, especially at the beginning, they should not prevent the employment of high intensities.

What differentiates these reactions from those which do is the actual condition of the patient regardless of the electrical dose,—the noisy, unreasonable complaint; the participation of all the organs in the pain; the brusque disappearance of the reaction when the current ceases; and, above all, the absence of a febrile movement, and the calm which always follows these storms, however violent they may be. These reactions are but little modified by intra-uterine applications of the continuous current. When excessive, they render the employment of high intensities impossible for the time, and should be foreseen and calmed by a general sedative treatment in the interval, and before the *séance* by vaginal or intra-uterine faradization.

The *non-negligible* operative reactions are the following: A sharp, burning sensation in the skin, caused by a defect in the preparation of the clay electrode or a lesion of the epidermis, and a true uterine or peri-uterine pain of a character wholly opposed to that of the false or nervous one; deep, smothered, only in part calmed by a diminution of the current, continuing after its arrest; not lessened, or but very little, by faradization, and followed by chilliness and afebrile movement. It is, however, the post-operative reactions which are of the greatest importance.

If a galvano-cauterization or galvano-puncture below 50 milliampères, though well supported, is followed after one or two hours, during the night or the next day, by an aggravation of the existing symptomatic state or afebrile movement that some extra-uterine incident—coition, fatigue, etc.—does not explain, mistrust and watch the progress that ever attends the disappearance of these symptoms, and renew the attempt. If not due to a spontaneous revival of the affliction or to an intercurrent lesion not related to the fibroid, these reactions were truly due to the treatment.

For greater certainty another trial may be made. If the second *séance* is a repetition of the first, or if this, under identical conditions, is followed by the same reactions, be sure there exists a contra-indication to the electrical treatment with high intensities, and surgical intervention is required. The method does not claim always to be a substitute for surgery. It claims only, within limits which we strive to enlarge and render more precise, to frequently replace it and always to aid it. When, at the beginning of the treatment, there is reason to fear an excessive reaction from the galvano-cauterization or galvano-puncture, on account of a recent peritonitis or cellulitis, vaginal galvanizations may be used as a preparation, by applying a carbon sound, bare or covered with antiseptic cotton, to the most accessible parts of the tumor.

Limits of Intensities—True Supportable Uterine Pain.

When a patient has supported one, or, for more certainty, two or three *séances* of experimental galvano-cauterization or galvano-puncture, of from 40 to 60 milliampères, with some of the operative or post-operative reactions we have described, it is beyond question a simple fibroid. As the absence of these reactions guarantees the absence of all complications, the intensities at the *séances* will be raised to the point of supportability, for true uterine pain, which we have learned to differentiate from the false or nervous, is the only limit of electrical intensity. But it cannot be the same for all *uteri*, nor invariable for the same one.

The uterus is a capricious organ *par excellence*, and, having an extreme functional instability, its sensibility may vary from one day, hour, or moment to another. Its tolerance must follow these variations, and hence the intensity for the same uterus must be proportioned to its varying sensibility. The practical conclusion is that only that dose must be given which the uterus can tolerate, without regard to the dose for another uterus, or for this particular one on a former occasion. Are not examples of this mobility furnished daily by physiology and therapeutics?

The alimentary ration or the medicinal dose sufficient for one is not for another, and the same ration or dose which was sufficient yesterday is not to-day. Through a violation of this simple but important law operators have seen smothered peri-uterine inflammations rekindled under

their treatment, and it will always be so whenever the law of true uterine tolerance is ignored or violated. To begin at the first *séance* with high positive intensities, though well tolerated, is to ignore or violate it, for there is no safeguard or reserve for the future; but still greater is the mistake to begin with high positive or, still worse, negative intensities when badly tolerated. The unpleasant incidents and accidents which have appeared in print, we affirm, were due for the most part to the culpable employment, from the first *séance*, of high intensities which were not, we are sure, well tolerated.

If we believe the absurdity that the uterus enjoys an immunity in Paris which is wanting in Vienna and Berlin, does it explain, if the law of uterine tolerance has not been violated, why in those places the electrical treatment of Dr. Apostoli is as painful as some writers have described it?

Indications

FOR GALVANO-CAUTERIZATION.

We will only enumerate these indications, preferring to remain in ground exclusively clinical, advancing more or less defensible hypotheses or indications for galvano-cauterization.

Galvano-cauterization addresses itself to the treatment of the greater number of fibroids. The endometritis which so often complicates this condition is directly, not secondarily, attacked. Galvano-cauterization is generally made with the platinum sound. The carbon sound is substituted where the uterine cavity is enlarged, or when there is abundant and rebellious leucorrhœa or hæmorrhage from the bottom of the uterine cavity. It establishes a direct contact with the whole mucous surface impossible to obtain with the platinum sound. It augments the surface cauterized by augmenting the surface of contact.

FOR GALVANO-PUNCTURE.

Galvano-puncture is an operation both of necessity and choice,—of necessity when the inaccessibility of the cervix prevents the introduction of the sound into the uterine cavity; one of choice when the gravity of the local or general state demands intervention and a rapid action. According to the statements of patients who have experienced both operations, galvano-puncture is followed by a greater and more rapid symptomatic amelioration.

Experience equally demonstrates that the automatical situation is more favorably and more rapidly influenced by it than by the galvano-cauterization. The abandonment of galvano-puncture in favor of galvano-cauterization, when the latter is not absolutely indicated, comes from a timidity, on the part of the operator, not justified, and which a larger experience will dissipate.

FOR VAGINAL GALVANIZATION.

Vaginal galvanization with the carbon sound is indicated when galvano-cauterization and galvano-puncture are impossible from any cause, and when, at the beginning of the treatment, they might produce excessive operative or post-operative reactions.

FOR EMPLOYMENT OF THE DIFFERENT POLES.

On account of its hæmostatic and antiseptic properties, as proved experimentally, the positive pole is indicated in fibroids accompanied by hæmorrhage and pain, and in those complicated with simple or specific endometritis or a chronic non-suppurating peri-uterine affection. The long-continued employment of the positive pole is followed by the contraction of the uterine cavity, principally the cervical canal; it presents no impediment to the menstrual flow, nor does it prevent conception. Neither is it a cause of dysmenorrhœa. Some patients have continued to menstruate without pain after positive galvano-cauterization has produced atresia; others who had dysmenorrhœa without atresia before treatment have found it to disappear after the treatment, notwithstanding the production of this condition in consequence.

The treatment, followed or not by atresia, has not prevented conception in fifty cases occurring among patients of the clinic or in the private practice of Dr. Apostoli and ourselves. These fifty cases will form the subject of a future essay, and it will appear that in some cases, far from preventing conception, it has manifestly favored it. Moreover, these atresias are easily prevented or cured. One or several negative cauterizations will effect a cure, or they can be prevented by intercalating in a series of positive cauterizations a negative one from time to time, in the desired situation.

On account of its denutritive influence and its effect upon congestion, the negative pole is applied to non-hæmorrhagic fibroids, to those which are only painful, and to those where menstruation is painful and not abundant; also to painful fibroids after positive galvano-cauterization has failed. Excepting these hæmorrhagic cases, the indications for the employment of poles, while true for the majority of cases, are not absolutely so. Some fibroids for which the positive pole is indicated are not favorably influenced by it, but are so by the negative, and *vice versâ*, while frequently the desired result is obtained by the employment of both.

AND OPERATIVE METHODS IN VAGINAL AND INTRA-UTERINE FARADIZATION WITH THE FINE-WIRE COIL.

The procedure is the same in vaginal and intra-uterine faradization, —the introduction of the sound into the vagina or uterine cavity, the application of the current *slowly* or *brusquely* until nervous quiescence

is attained, however much time may be required to accomplish it. The anæsthesia or insensibility of the uterus which denotes nervous quiescence is obtained when the patient ceases or almost ceases to feel the current, and when there is scarcely any reaction from a sudden change in the strength of the current.

The *slow* procedure consists in raising progressively, little by little, the strength of the current to its maximum; the *brusque* procedure consists in doing so in an instant or in a very short time, whether tolerated or not. The latter is very painful and is applicable only in cases of nervous trepidity, which are a little sensitive to the faradic current. Vaginal and intra-uterine faradizations are indicated when the excessive general or local sensibility renders the introduction of the sound painful or the employment of high intensities impossible. It is also an aid to diagnosis in doubtful cases, as we have demonstrated in the preceding pages.

Duration of the Séances.

The duration of a galvano-cauterization with the platinum sound and the galvano-puncture is, in general, five minutes. The duration is shorter in the case of uterine intolerance due to hysteria or a lesion of the appendages. In hysteria and inflammation of the appendages uterine tolerance is very capricious. An intensity well supported during the first two minutes of the *séance* may not be so during the third or fourth. It is necessary to bend to this capriciousness and accommodate the length of the *séance* to it. We have indicated the artifices to be employed when dealing with a local hysterical condition.

The galvano-cauterization with the carbon sound is from six to nine minutes; it depends upon the extent of the uterine cavity to be cauterized, each portion requiring three minutes.

Faradization should be continued until the arrival of general and local nervous quiescence, which is recognized by the characters we have described.

The Time for Operation.

The galvano-cauterization and galvano-puncture may be made at any time,—in the presence of the pains during menstruation, if of too long duration or too abundant; when a hæmorrhage is at its height,—provided neither one or the other of these symptoms is accompanied by fever, nor is symptomatic of an acute condition.

Faradization may be performed at any time, even during an acute or subacute attack.

The Interval between Séances.

The interval depends upon the nature of the application, the state of the subject, and the reactions. A *well-supported* galvano-cauterization may be repeated every other day; but when several *séances* are followed

by a slight aggravation of some symptoms, as sometimes happens, it is well to suspend the treatment. This event often marks the beginning of the expected amelioration. Galvano-cauterization well supported *should be repeated* every third day, and may be repeated every day when a quick action is required, as in hæmorrhage.

Dr. Apostoli was accustomed to allow an interval of eight days between the galvano-punctures. With his new trocar he operates twice a week. The custom at the clinic cannot serve as an example upon this point, for the patients are too numerous to be treated every two days. Unless, therefore, there is some urgent reason,—hæmorrhage, for example,—they are treated alternately once or twice a week. Many are benefited by the first treatment, and afterward come only occasionally; others come only at very long intervals for the benefit which they say invariably follows each application.

Faradization can be repeated every day or several times a day.

Séances Necessary for the Amelioration or Symptomatic Cure of a Fibroid.

The number cannot be precisely stated in advance. It depends upon a variety of factors,—the kind of fibroid and the duration; the age of the subject and the gravity of her condition; the assiduity as regards attendance; the nature of the *séances* and the intensities employed. Fewer are required for an interstitial than for a submucous or subperitoneal tumor; fewer for one of recent growth and without complications than for one of long standing complicated with a peri-uterine lesion, or a nervous condition aggravating her state and rendering the employment of high intensities impossible, thus obliging the continual use of those of medium strength. Fewer, likewise, for a fibroid without hydrorrhœa than when it exists, and for a hard tumor than for a soft one.

Fibroids in young subjects, those with a grave and complete symptomatology, those which have profoundly affected the general condition, will require a greater number. A fewer number of galvano-punctures will be required than of galvano-cauterizations; finally, and above all, the fewer number will be required as the employment of high intensities has been possible. The exact mean number required cannot be established by reference to the patients at this clinic. As we have already said, their great numbers, their social condition, and the loss of time in coming to the clinic and remaining there prevent the greater number from being treated as often as they should be or as they would wish.

The results suffer from the long intervals between the *séances* when they should be frequently repeated; so that the treatment is extended over a long period and a greater number of applications are required. Conversely, some patients, from gratitude for the benefit received from the treatment, do not desert the clinic even after the symptomatic state that brought them there has vanished; and we have seen them exaggerate

the gravity of their condition and simulate a relapse in order to obtain, in being treated, the benefit that each *séance* procures.

Results of Electrical Treatment—Anatomical Results.

It is permissible to say that the diminution in volume of fibroid tumors, although not constant, is observed in a large proportion of cases treated electrically. The degree of reduction varies much, and depends upon several factors, of which the principal are: In the first place, the texture of the tumor; that is to say, the quantity more or less great if the muscular tissue is in proportion to the fibrous tissue which enters into its composition. In the second place, the situation more or less interstitial or subperitoneal; and we will add, in the third place, the chronicity. It is readily conceivable that a tissue of recent formation would be more easily and more actively modified in its nutrition, that the process of disintegration would be more complete, under the influence of the electric current, than in a tissue whose organization is far advanced and already chronic.

Whatever may be the explanation of the fact, it is rigorously established by clinical observation that soft interstitial fibroids of recent formation afford the most favorable conditions for a partial or complete disintegration under the influence of the electric current. Parallel to the reduction in volume, there is produced another change, which is perhaps more constant than the first. It is the liberation of the tumor, its tendency to become pedunculated, to enucleate itself either toward the abdominal or the uterine cavity, according as the point of implantation in the wall or the organ is near the one or the other of these cavities. It becomes more and more probable as the treatment progresses, until sometimes it gives the sensation of a body completely free in the abdominal cavity, and under the pressure of the hand is capable of extensive displacements. This same process of enucleation, instead of carrying the tumor toward the peritoneal cavity, may cause its pedunculation in the uterine cavity and its passage through the cervical canal, the vagina, and the vulva. In this case the patient is literally *accouche* of the tumor.

During the first fibroids treated electrically by one of us in private practice, enucleation took place with great rapidity. Seven galvano-caustic *séances*, in the course of the first month of treatment, were sufficient to bring the polypus to the vulva. Indeed, it is a process which is produced spontaneously, at times, though much more slowly; but is then generally accompanied by abundant and repeated hæmorrhages, which may imperil the existence of the patient. This dislocation of fibrous tumors is not the last anatomical change determined by the electrical treatment. There is observed, principally in voluminous fibroids, a real segmentation of the primitive moss into several lobes of variable size and number. This result is due to the re-absorption of the

atmosphere of cellulitis, which ordinarily surrounds these tumors and imbeds in the same moss the more or less numerous segments which compass it.

Thus, a tumor which at the beginning of the treatment was solidly wedged in and appeared to be a single mass, compact and immobile, becomes, after a certain number of *séances*, free from its adhesions and divided into several lobes capable of gliding and moving freely upon each other. This explains how the phenomena of compression disappear and cease to be a source of discomfort to the patient, even when the tumor remains voluminous. We will return to this again when treating of the symptomatic amelioration which follows the electrical treatment.

Well-authenticated cases of the total disappearance of fibro-myoides are no longer rare in the annals of science. It has occurred several times at the clinic of Dr. Apostoli, who never consented to publish them from the fear of appearing to attach too much importance to evidence of preceding considerations relative to the changes observed in the volume of fibro-myoides in consequence of an electric treatment properly applied. We can synthetize them in the following formulæ: 1. A diminution in volume is observed frequently, but not constantly, and is very variable in extent. 2. The total disappearance, though rare, is sometimes observed. 3. The arrest of development is the rule.

INVESTIGATION AND POSSIBLE CAUSES OF ERROR IN APPRECIATION OF RESULTS.

Palpation, external measurements, and hysterometry are the different means which permit the appreciation of the changes which have taken place in the volume of the uterus and the tumors which are developed in it. Each of these methods of investigation may at times prove unfaithful and give rise to errors, and it is well to know under what circumstances. Some of them are the following: When there is simple hypertrophy—not fibrous—of the organ in chronic metrites, for example, the electrical treatment causes diminution of the cavity, which it is usually easy to appreciate by hysterometry. But, on the other hand, it happens sometimes, in the case of a fibrous uterus with subperitoneal fibroids, that the volume of the tumors diminishes considerably after a treatment sufficiently prolonged, although hysterometry reveals no reduction in the depth of the uterine cavity. Such is the case in patient No. 2477, at the clinic of Dr. Apostoli. She presented herself the 6th of November, 1890, with an interstitial fibroid, in great part subperitoneal, occupying the external and left lateral aspect of the uterus. The tumor extended beyond the umbilicus, and an hysterometer indicated nine and a half centimetres. She was treated from November, 1890, until January, 1892, with an interval of three months,—from July to November, 1891. There was made, in all, nineteen intra-uterine positive galvano-caustic applications and five with the negative pole. The patient, who is 41

years of age, continues to menstruate with regularity. Four months after the cessation of this treatment there was found, upon examination, a tumor which scarcely surpassed the pubes. However, hysterometry still indicated nine and a half centimetres, exactly as before the treatment.

Hysterometry, then, does not constitute a means upon which we can always rely, and an absolute method of appreciating the degree of reduction of fibroids. In the present case, although palpation combined with the vaginal touch indicated a diminution of one-fourth or one-fifth in the volume of the tumor, the sound penetrated to the same depth as before the treatment. It is true that scarcely three months has passed since the treatment was suspended, and it is rational to presume that, the tumor continuing to diminish, the uterine cavity will in itself, in its turn, undergo a certain reduction during the following months; another fact deserves not less to be noted,—the almost complete disappearance of the voluminous subperitoneal tumor developed in a uterus whose cavity, much enlarged, preserves yet the same dimensions.

We may add, *en passant*, that the case of this patient serves also to demonstrate that, contrary to the opinion of certain authors of great authority, the reduction in volume of fibrous tumors does not always manifest itself during the period of active treatment, and may even begin only during the months which succeed it.[1] This theoretical view may be exact as regards the resolution of the atmosphere of cellulitis which surrounds the tumor, but, as for the reduction of the tumor itself, experience demonstrates every day that there is no foundation for such expectations.

Certain subperitoneal or interstitial fibroids present a development more or less great, while the cavity of the uterus itself preserves, if not its normal dimensions, at least an approach to it. In these cases also hysterometry is of restricted utility to measure the real anatomical reduction of tumors after the electrical treatment. Another source of error, more apparent than real, and which could only mislead the patient,—for the physician can always detect it by a somewhat attentive examination,—is the development of a layer of subcutaneous adipose tissue which is produced toward the end of a somewhat prolonged electrical treatment, and gives to the abdominal wall sometimes a considerable increase of thickness. These patients, not seeing the abdomen diminish, may think that the volume of their fibroid is not modified, when in reality it is perhaps already notably reduced. It is indispensable to take into account the thickness of this subcutaneous layer of adipose tissue of recent formation, in the external mensurations which will be made during the course and at the end of the electrical treatment.

Dr. Apostoli uses for this purpose compasses of a particular form,

[1] Tripier, in particular, advances at different times the opinion that the reduction is evident from the beginning of the treatment, and "that a considerable number of *séances* is not necessary to enlighten us upon what we have to expect."

with which he measures a fold of the skin of the abdomen, and half the distance the arms of the instrument are separated gives the real thickness of the abdominal wall. Sometimes, however, the augmentation is real (Mod. P., No. 2201 of the clinic), and in this case the insufficiency of the intensities employed during the treatment can be invoked. This patient, whose record, interesting in several respects, will be published elsewhere, presented in fact complications, as regards the appendages, which necessitated the employment of doses too feeble to actively modify the nutrition of the existing fibroid.

Finally, in a certain number of cases, relatively few, the augmentation of volume is produced without our being permitted to invoke the insufficiency of the treatment or of the intensities employed. These refractory cases are either very hard, old subperitoneal fibroids; tumors of rapid development; tumors of fibrocystic nature, frequently accompanied by an abundant watery discharge; or yet neoplasms which, though benign in appearance, may remain stationary for a considerable period, but whose true character is finally revealed, and whose fatal cause the electrical treatment is powerless to hinder.

SYMPTOMATIC RESULTS.

Such are the anatomical results which we can legitimately expect from a well-conducted electrical treatment. To ask more of electricity is to expose one's self to disillusions and miscalculations. At least, these results are real and well established clinically, however they may be regarded by some who regret everything contrary to their own opinion, and cannot endure that any progress should be accomplished outside of themselves.

We will now pass to the symptomatic results. Here the action of electricity is more apparent and more rapid, as well upon the general condition as upon the various morbid derangements which exist. The physiological level is always lowered, in patients the subjects of fibroid tumors, even when there is not a direct reduction of the forces from the hæmorrhages which accompany them.

We will not trace a complete symptomatic representation of this affection,—one of the most serious which threatens woman during the active period of her existence. We will limit ourselves to recalling the most usual symptoms,—the hæmorrhages, the pains,—as well those localized in some part of the tumor as those due to pressure exercised upon the organs and neighboring nervous trunks.

It may be affirmed, without fear of exaggeration, that, of all the therapeutic agents employed to-day, more is capable with electricity, from the point of view of the efficiency, rapidity, and certainty of its action in arresting hæmorrhages, calming the pains, arousing the vitality, and repairing the forces,—in a word, producing a transformation, which is sometimes observed with surprise to follow after the first application.

As to the functional disorders which habitually follow in the train of this affection,—dysmenorrhœa, amenorrhœa, vesical troubles, constipation, etc.,—it is still by the use of electricity that we have the best chance to see them disappear or amend.

If, notwithstanding the employment of high intensities, brought into honor by Dr. Apostoli, it yet happens but too often that the electric current remains powerless to cause the disappearance of fibroids, or even to notably diminish their volume, it is not so of their symptomatic cure; in the great majority of cases which present themselves in practice the cure is almost assured and permanent, providing the treatment is applied as it should be. We except, however, be it understood, tumors which are not amenable to this treatment, of which we have already spoken.

But the true triumph of the electrical treatment is the cure of hæmorrhage. There are but few cases absolutely rebellious to it. As for us, for more than four years we have followed attentively all the patients at the clinic of Dr. Apostoli, embracing a very respectable number of hæmorrhagic fibroids. We have not yet encountered a single one where hæmorrhage was not arrested, save in cases of malignant neoplasms, which, up to the present time, it is not permissible to inscribe among the pathological conditions capable of being modified by electricity. In particularly rebellious hæmorrhagic cases it has been necessary to modify the treatment several times, and to utilize faradization, galvano-cauterization, or the sinusoidal current, in succession or alternately, as the efficacy of each seemed to diminish.

In cases of hæmorrhage rebellious to electrical treatment the possibility must always be borne in mind of a process of overelevation on the part of the tumor in the direction of the uterine cavity, or of some ovarian complication,—ovaritis, peri-ovarian inflammation, etc. It is also necessary to inquire if there be not some diathetic cause engrafted upon the local affection, and impressing upon it its particular characteristics; thus, there are women subject to repeated uterine epistaxis, without any character of periodicity, and analogous to nasal epistaxis. These discharges return without any real cause capable of explaining them, and without our being authorized to attribute them to the existing local lesions. They are diathetic epistaxes. In questioning these patients it may happen that we shall discover that they have had, at one epoch or another of their existence, notably before the establishment of the menstrual function, nasal epistaxes coming on without regularity and sometimes extremely abundant.

Beyond these exceptional cases the electric current constitutes an efficacious and trustworthy means of controlling the hæmorrhages which accompany fibroid tumors of the uterus. The rapidity of its action is, however, quite variable. It is not absolutely rare to observe, after the first *séance*, the arrest of a hæmorrhage already of several months' duration, particularly if the uterine periphery is in a condition which permits

without danger, upon the first occasion, the application of a sufficiently energetic current (100 milliampères, for example). Habitually this result is obtained only after several applications, usually from three to ten.

Finally, cases are found, principally when the uterine mucous membrane is the seat of fungosities, in which the hæmorrhage, controlled by one or several *séances*, returns after several days or some weeks, in spite of the regular continuation of the treatment during the time it was absent. These cases of fungous metritis require energetic galvano-cauterizations to destroy the fungosities, and implicate a considerable part of the thickness of the diseased mucous membrane, in order that it may be replaced by a new formation of greater resistance and less vascularity. Moreover, it is indispensable that the greatest possible amount of intra-uterine surface should be submitted to the polar action of the current; and it is here that the finger-shaped carbon electrodes employed by Dr. Apostoli in these special cases find their principal utilization, being selected of a diameter proportionate to the extent of the uterine cavity. All the details relative to the employment of these carbon electrodes have been explained when treating of the operative technique.

Endometritis is far from being the only factor to be considered in the production of these hæmorrhages. Every circumstance capable of causing congelation of the uterus and ovaries may accidentally determine a hæmorrhage. They constitute at a given moment a new pathological element which, superadded to the already existing alterations of the uterine mucous membrane, favors the reproduction of the sanguineous losses or aggravates them. It is not a matter of indifference as regards the opportuneness and the modifications which, according to circumstances, the treatment must undergo, that we should seek to attribute to each of these factors its proper share in the genesis of this symptom.

Next to the hæmorrhages, and of about the same frequency, pain is the most distressing symptom of uterine fibroid tumors. But it is also, of all the complications, the one which amends or disappears most easily under the influence of the electric current. This result is obtained not only by the proper sedative action of the current upon the nervous filaments which suffer, but, in addition, by the decongestion, the denutrition, and, as a corollary, the reduction in volume of the tissues which exercise a painful pressure upon these parts. Here, as with hæmorrhages, it is not unimportant, as affecting the selection of the method of intervention, to seek the origin of the pain and to determine, as exactly as possible, the part contributed by each factor—whether local, reflex, central (ovarian and nervous), or diathetic—to the genesis of the symptom, in order to oppose the most appropriate electrical procedure.

Those considerations apply equally to other symptoms—dysmenorrhœa, amenorrhœa, vesical troubles, etc.—whose study requires each a special chapter.

Causes of Failures.

They may be arranged under three heads, according as they are due to: 1. The operator. 2. The patient. 3. The disease.

The treatment may be defective and the desired result not attained because the time has been too short and the number of *séances* insufficient. This cause of failure is generally due to the patient, who, too confident in the result obtained from the first application, believing herself cured because the symptoms which obliged her to have recourse to the treatment are amended, too quickly suspends her visits to the physician. In such a case it may happen that the amelioration is imperfectly maintained or continuous for a time only. The evil will be inconsiderable and reparable, for it is likely that a return of the primitive symptoms will oblige the patient, after a longer or shorter time, to recommence the treatment prematurely interrupted, and to continue it this time until the cure is assured.

The social condition of the patient is an important factor which may sensibly influence the result of the electrical treatment. With women in comfortable circumstances, whose means permit the utilization of all the resources of hygiene and allow them to consecrate the necessary time to the care of the health, the chances of failure are evidently less than with women of the people, who are obliged, in order to live, to devote themselves to heavy tasks which they cannot abandon during the course of the treatment. These women find with difficulty the few hours of repose after each application which would assure the beneficial effect, and they are obliged, even the same day, to return to their arduous occupations. Moreover, they are often prevented, by this circumstance, from receiving the treatment with the frequency demanded by the condition of the tumor. These defective conditions, it can be easily perceived, are sufficient to seriously compromise the results and occasion a failure where the state of the patient will otherwise permit the entertainment of well-grounded hopes of success.

The nervous condition of some patients might impose upon the inexperienced operator, causing him to believe that the electricity was badly supported on account of the possible existence of complications at the uterine periphery, and induce him to apply the current with too much caution and in a more feeble dose than the case required. The response of the nervous system to painful impressions in hysterical women takes a character quite special, which is recognized at once by the experienced observer just as the accoucheur can diagnose without hesitation, at a distance, simply by the character of the cries of the parturient woman, the stage at which the labor has arrived. The complaint of pain with nervous women is entirely different from that of a woman who suffers from inflammatory lesions of the pelvic organs. There is about the former abruptness a noisiness not presented by the latter, which is more concentrated and

genuine. The former is an outburst, so to speak, and all on the surface; it also disappears brusquely when the determining cause ceases to act. The latter is deep, silent, and survives the cause which gave it birth.

When the operator finds himself with a patient whom he sees for the first time, and there remains a doubt about the diagnosis, he can, to remove it, employ a little subterfuge which we have many times heard recommended by Dr. Apostoli. It is the following: Raise progressively the intensity to the extreme limit which we wish the patient to tolerate, but which seems to occasion too great a degree of pain. Then surpass this limit to a proportionate extent,—15, 20, or 30 milliampères, for example, —until the pain becomes intolerable; then suddenly lower the intensity to the original point. If inflammatory lesions do not exist the pain ceases at once, and the patient tolerates afterward, without suffering, an intensity which before occasioned so much pain as to be insupportable. In the case of inflammatory lesions, on the contrary, the brusque transitions from a given intensity to a lower one does not bring immediate or complete relief, as when the pain is purely nervous. In the former case the pain persists, although less acute, and there is only a progressive abatement.

Some cases may present themselves in which perhaps all uncertainty may not be dissipated after the experiment just described; the post-operative reactions will then serve as a sure criterion. The observation of these reactions is of capital importance, and we cannot too earnestly direct the attention of those who are beginning the study of the application of electricity to gynæcology to a careful consideration of them. They constitute the most reliable guide for the dose of the current to be employed at each *séance*, and the indications which they furnish cannot be neglected with impunity.

If from want of experience one allows himself to be alarmed by the exaggerated complaints of a nervous woman, who manifests brusquely an intolerance more apparent than real, he is liable to remain below the efficacious dose, and the treatment will be insufficient. If, on the other hand, from the beginning, currents of too great intensity are incautiously applied, or no account is taken of the reactions which follow applications of medium strength, in the case of a patient with lesions which the most skillful touch cannot detect (a circumstance more frequent than it is supposed to be or than we wish to acknowledge), we are exposed to the danger of rekindling inflammation which was latent or in a period of quiescence, and by so doing subject the patient to the most serious risks.

This article is not polemical, and we wish to abstain from all allusions which could be interpreted as a criticism of the skill of any one, but we are obliged to state that in the greater part, not to say the totality, of unfortunate cases published in Europe and upon the other side of the Atlantic, as due to the electrical treatment, the responsibility for what happened should rest not upon the electrical treatment, but upon those who

applied it imprudently and without regard to the precise and complete set of rules formulated by Dr. Apostoli.

To cite one example only,—a communication made, at the beginning of the year 1891, before the Boston Society for Medical Improvement, of the statistics of thirty-five cases of fibroid tumors treated by electricity *à la Apostoli*, or so at least the author claims. In the thirty-five cases there was one death which the author attributes to septicæmia occasioned by the treatment. He regrets that an autopsy was not made, and we regret it certainly as much as he does, because simply from reading his observations we have no doubt that an autopsy would have unveiled the *corpus delicti*, which would have been found to be a suppurating inflammation of the appendages.

But what is to be particularly regretted is that, notwithstanding the violent reaction following each galvano-caustic application, the operator persisted in repeating them, at intervals of scarcely a few hours, with intensities of 115, 125, and 150 milliampères, never less than 80 milliampères, and for periods varying from five to nine minutes. With such a brutal method of procedure, so completely devoid of medical tact, we cannot keep from observing that the unfortunate result does not surprise us; it must infallibly have happened. What also surprises us is that it occurred but once, and that, in spite of everything, the statistics of the thirty-five cases remained so favorable. If the writer supposes, as he ingenuously states, that he submitted these patients to an electrical treatment *à la Apostoli*, we are sorry to undeceive him; but that manner of applying it conforms in nothing to that of the author of the method.

In electricity, just as in ordinary medical therapeutics, the question of dosage is of primary importance. To apply in each case the proper dose without surpassing it,—this is the most important study in the field of medicine, and also the most becoming, for upon it depends the success or failure in the treatment of disease. There is not in medicine a more commonplace axiom, nor one more frequently misunderstood. Of this we need no better proof than the gravity with which the schools continue to teach the *maximum* and *minimum* dose. The same is not less carefully set forth in the guides and manuals, which, considering the profusion of new medicinal agents in our time, constitutes in itself, *par parenthesis*, a sufficiently arduous study.

It is, moreover, to this routine of what is called medicinal doses that may be attributed the greater part of the *homicides* from *imprudence* which the lay and medical press chronicle daily. Not in electricity more than in general therapeutics does there exist *maximum* and *minimum* doses.

There exists, in reality, only the *efficacious dose*. It is evident that this dose must be eminently variable, according to a great variety of circumstances.

The particular constitution of each patient of the age, tolerance,—

that is to say, the manner of reaction in reference to the medicinal agent, —the nature, acuity or chronicity of the disease, the activity of the agent, the opportuneness of the moment of intervention, etc., comprise so many factors, no one of which can be neglected. The rule is absolute to go on progressively until the effect sought for is obtained. To fall short or to go beyond this would be illogical and the consequence in either case a failure.

The interval which it is proper to leave between two *séances* should be regulated with care, for it must be varied in accordance with a number of circumstances having reference to the nature of the fibroid (consistence, period of growth, situation, topography, etc.), the presence or absence of concomitant peri-uterine lesions, the temperament and diathetic constitution of the patient, to her electrical tolerance and to the resistance of the disease to the treatment. It is certain that a simple fibroma, of firm consistence, without complications as regards the appendages, of quite long existence, in the case of a woman whose nervous system is not very excitable, will require longer, more energetic, and more frequently-repeated applications than when opposite conditions exist.

The nature of the endometritis accompanying the tumor, the acuteness and pathological cause of the pain, the abundance and frequency of the hæmorrhages, and the causes which provoke their appositions constitute so many elements which must be considered, in order to regulate after each *séance* the date of the next one, to judiciously push or relax the treatment in accordance with the result of the preceding application, —in a word, obtain for the patient, at a given moment or for the whole period of treatment, the greatest possible benefit. When the interval is too long between *séances*, the benefit obtained from the last is too nearly exhausted before the effect of another comes to re-inforce it, in which case there is, so to speak, a continued re-commencement or a "mock time" without any appreciable change in the situation. Under these circumstances it is necessary that the intervals should be shortened in order to maintain the patient in a state of constant toleration, as uniform as possible, through the period of treatment, and that the modifications produced by each new *séance* should be added to the preceding ones before they are completely dissipated.

The applications can be repeated without disadvantage every three or four days, in the case of a simple fibroid during the active period, if, when the treatment is more advanced, a longer interval can be allowed, according to circumstances. If, on the contrary, after a certain number of applications, although well supported and the integrity of the appendages is not questioned, there is developed some functional derangement which seems to denote by its recurrence a tendency toward the establishment of a state of permanent congestion of the uterus and other pelvic organs,—for example, menstruation returning before the habitual epoch and with unaccustomed abundance; intermittent sanguineous discharges

coming on without provocation or simply upon slight fatigue,—these discharges must not be confounded with those which frequently follow the galvano-caustic applications, and it is then proper to increase the interval and repeat the *séances* only every five or six days once a week for a certain lapse of time, to return to a more active treatment if the conditions become more favorable or if the advance toward a cure is being too slowly accomplished. There is no contra-indications to the electrical treatment of a subperitoneal fibroid already of long standing, and it is evident that under such circumstances one must not expect to obtain any considerable anatomical modifications; but if the treatment is continued for a long time there is a chance not to have to score a failure, particularly from the point of view of a symptomatic cure.

The same cannot be said of tumors of very rapid development, of fibrocystic tumors, and neoplasms of a malignant nature. Here the electrical treatment is contra-indicated.

The existence with the fibroid of an inflammatory lesion of the uterus, or of any other pelvic organ, does not constitute a formal contra-indication to the electrical treatment, provided, however, that the inflammation is not at an acute period.

This complication, when it exists,—and it is encountered daily in practice,—nevertheless imposes upon the operator increased watchfulness as regards the susceptibilities of the patient, in order to modify the manner of procedure in the form of the treatment in accordance with the indication of the moment.

A DISCUSSION OF THE ELECTRO-THERAPEUTIC METHODS OF APOSTOLI AND OTHERS.

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The title of this paper should not lead the reader to expect either a controversial treatment of the electro-therapeutic methods introduced by Professor Apostoli, of Paris, or an exhaustive consideration of all electro-therapeutic methods in use, but rather a presentation of a number of fragmentary facts which are of practical interest to the therapeutist, and which may not have been fully considered by other contributors in this work.

My personal experience in electro-therapeutics began in 1875, when I was a pupil-assistant of the late Dr. Geo. M. Beard, at that time the leading electro-therapeutist in this country. That Dr. Beard did much toward placing electro-therapeutics upon a scientific basis all who are familiar with his work will readily acknowledge, although the absence of practical instruments of precision for the measurement of electrical currents and electrical work prevented his carrying his original researches beyond the preliminary state; so that they have been quite overshadowed by the brilliant achievements of more-recent investigators, especially the notable work of Prof. George Apostoli, to which must be fairly attributed the veritable revolution in electro-therapeutics which has been witnessed within the past half-dozen years, and the complete recovery of a most valuable therapeutic agent from the low level, almost bordering upon charlatanry, to which it had fallen, through the indefiniteness of therapeutic indications and uncertainty of results which attended the use of this agent prior to the recent advances in its therapeutic use.

During the last eighteen years I have made constant use of various forms of electrical currents, especially in gynæcological practice, making personally, with the aid of my assistants, for a number of years back, not less than 20,000 applications annually. I have taken occasion to investigate the various modes of using electricity therapeutically which have been brought forward, especially those of Prof. G. Apostoli, and feel no hesitancy in giving to him full credit for having been the first to place upon a thoroughly rational basis the *modus operandi* of electro-therapeutics.

The chief interest in electro-therapeutics has heretofore centred about the galvanic and faradic currents, although the value of the static current in cases adapted to its use is unquestioned. I have made much use of the last-named current during the last ten or twelve years, but

consider its value so small and its application so limited, when compared with the indispensable utility of the galvanic and induced currents, that I shall devote no space to its consideration.

Within a few years much interest has been developed in a newly-described form of an electric current, termed "sinusoidal" by d'Arsonval, by reason of the regularly sinusoidal form of the curve produced by the current when graphically represented. The current is obtained from a magneto-electrical apparatus. Further mention of this current will be made in a subsequent portion of this paper.

The most remarkable effects claimed for electrical applications in any form have been the results obtained through its use by Apostoli and many others in the treatment of uterine fibromata. The great frequency with which this neoplasm is encountered, and the not infrequent obstinacy with which it resists all non-surgical therapeutic measures, has given to the employment of the galvanic current, in this class of cases, an importance superior to that of any other single therapeutic use.

The time which has elapsed since the presentation to the medical profession, by Professor Apostoli, of his method of using the galvanic current in the treatment of uterine fibroids, which enabled him to employ currents of far greater quantity than had ever been previously attempted, is now sufficiently long to enable a fair estimate to be made of the value of this means of treatment.

Apostoli himself, after the treatment of several hundred cases, reports permanent benefit in 95 per cent. of his cases.

Keith, formerly of Edinburgh, now of London, after several years' employment of this method, also having treated several hundred cases, reports even better results than those claimed by Dr. Apostoli himself.

G. Betton Massey has reported over 50 cases of tumor treated by this method, which he divides, as regards results, into five classes, as follow: (1) Cases of complete anatomical and symptomatic cure, the tumor completely disappearing,—7. (2) Cases in which the tumor was considerably diminished in size, and all other symptoms relieved,—22. (3) Cases in which the tumor was not diminished in size, but all other symptoms relieved,—7. (4) Cases in which the tumor was not diminished in size nor symptoms relieved,—2. (5) Case made worse by treatment,—1.

In 60 cases of my own, carefully tabulated and similarly classified, reported in a paper prepared for the Louisville meeting of the Mississippi Valley Medical Association, in 1890, the results were as follow: (1) Complete cure,—14. (2) Cases in which the tumor was considerably diminished in size and all other symptoms cured, patient being restored to good health,—17. (3) Cases in which the tumor was not diminished in size, but all other symptoms relieved,—11. (4) Cases in which the tumor was not at all diminished in size and other symptoms but slightly relieved,—5. (5) Cases in which the patients were not long enough under

treatment to give the method a fair trial, only two or three applications of the treatment being made,—4. Of the cases reported as made worse, or not benefited, only one case was actually made worse, and three of the others were slightly benefited, although not sufficiently so to justify me in presenting the results as satisfactory.

With reference to the class of patients most likely to be benefited, I find, by a study of my cases :—

1. Of 32 cases of interstitial growth, 14 were cured; in 9 the tumor was diminished in size and the other symptoms cured; in 6 the tumor was not diminished in size, but all the other symptoms were cured; and in 3 the tumors were not diminished in size, although the patient was partially relieved of the other symptoms.

2. In 9 cases of subperitoneal growth the patient was either not at all benefited or made worse in 4 cases; but slightly benefited in 1 case; relieved of other symptoms, although the tumor was not diminished in size, in 2 cases; and cured of other symptoms and tumor diminished in size in 2 cases.

3. In 15 cases of interstitial and subperitoneal growth there was complete failure in 5 cases, slight benefit in 1 case, relief of symptoms without diminution in the size of the tumor in 4 cases, and relief of all symptoms with diminution in size of the tumor in 5 cases.

The fact that tumors do not disappear entirely as the result of electrolytic treatment has been urged, as the writer thinks, unfairly, as an objection to this mode of treatment. In reply it is to be said :—

1. That complete disappearance of the tumor does occur sometimes ; of the 14 cases which I report above as entirely cured the tumor absolutely disappeared in 5 cases, and in the remaining 9 cases the diminution in size was so great that scarcely a trace of the tumor was left behind. Keith reports a number of cases of complete disappearance of tumors. G. Betton Massey reports 7 cases of complete anatomical cure, and in a letter recently received from him, Dr. W. H. Walling, of Philadelphia, reports 1 case of anatomical cure in which the patient was examined both before and after treatment by a number of eminent gynæcologists ; so that there could be no possible doubt as to the efficiency of the electrolytic current, although the patient had been previously pronounced incurable. In this case only 30 milliampères of current were used, treatment being employed once or twice a week during six months.

The fact that cases of subinvolution of the uterus may be mistaken for an interstitial fibroid growth cannot be disputed, as the uterine enlargement, even in cases of subinvolution, is not always symmetrical in character. Nevertheless, it cannot be supposed that so accomplished a surgeon and acute diagnostician as Dr. Thomas Keith should be mistaken in all the cases which he has reported as complete anatomical cures. If those who are opposed to this mode of treatment assume the position that the uterine fibroid is intrinsically incurable by the galvanic current,

and then assert that every case cured is a case of subinvolution, there is, of course, no chance for argument, and time spent in a discussion of this question on this basis would be worse than wasted. The difference, from a therapeutic stand-point, between a case of chronic subinvolution which has resisted all ordinary therapeutic means and an interstitial fibroid growth does not seem to be very great; and it is reasonable to suppose that a remedial agent capable of effecting a radical cure in a pronounced chronic case of uterine subinvolution could not be without decided effect upon a neoplasm of the nature of a uterine fibroid, especially as it is well known that retrograde tissue metamorphosis may be much more easily induced in fibrous tissues than in more highly organized tissues.

2. Complete disappearance of a uterine fibroid is not the uniform result of the natural process of cure through the appearance of the menopause. I have not infrequently met cases, long after the menopause had been fully established, in which the uterus was covered with lumps, sometimes of considerable size, the shriveled and innocuous remains of large and exceedingly troublesome fibromata which had previously existed. It is unreasonable to expect that electricity or any other agent should be more effective than nature's own means of cure for cases of this sort.

3. The Tait-Hegar method of removing the appendages, while an eminently successful method, and one the utility of which, in appropriate cases, cannot be disputed, does not accomplish more in the way of reducing the tumor than is accomplished by the natural mode of cure, since this operation has little other effect than to induce premature occurrence of the menopause.

4. I have taken pains to collect the opinions of a number of eminent gynæcologists, some through their published works and papers, and others through personal correspondence, and I think it may fairly be said that the majority of gynæcologists decidedly favor the employment of the galvanic current in suitable cases of uterine fibromata, although there are to be found those who condemn its use altogether. The most decided opponents of the method are to be found among gynæcological surgeons, especially those whose work in the surgery of the pelvis and abdomen has been attended by the most brilliant success. Mr. Tait is too busy with his operative work to have time for any kind of non-surgical gynæcological practice, especially that which requires so much time and attention to technical details as does the employment of electrolysis in the treatment of uterine fibromata, or, indeed, any other grave condition to which it is applicable; nevertheless, Mr. Tait refuses to operate either for the removal of the appendages or the performance of hysterectomy in a large number of cases which are considered proper subjects for the employment of electrolysis by the advocates of this method, and which are doubtless capable of being benefited to a greater or less degree by electrical means. At any rate, this was Mr. Tait's practice, according to the observation of the writer when acting

as his pupil-assistant a number of years ago. Dr. Joseph Price, of Philadelphia, does not hesitate to perform the major operation of hysterectomy upon a large proportion of the cases which most other surgeons would treat by palliative means, not excluding those who have no faith in the value of electricity for this class of cases, and the success of the last-named surgeon apparently justifies him in his choice of a method which is certainly more hazardous, and could not be undertaken by a less-experienced surgeon than himself without a degree of mortality which would certainly soon bring the operation of abdominal hysterectomy into disrepute. The writer has endeavored to make a careful study of both the surgical and the electrolytic methods of dealing with these cases, and believes the only rational position to be the one which recognizes the utility of each method in its own particular class of cases. Of 9 cases occurring in my own practice, already referred to, in which the results of the electrolytic current were found to be unsatisfactory, 5 were cured by the removal of the appendages, Dr. Lawson Tait operating in 1 case and myself in the other 4. In the opinion of the writer, patients suffering from troublesome uterine fibromata will only have a thoroughly fair chance for recovery when gynæcologists have come to recognize the true value of both the electrolytic and the surgical modes of dealing with these cases.

Since electrolysis was first proposed as a means of dealing with fibromata of the uterus, and as a substitute for surgical methods, the mortality from the operation of ovariotomy and hysterectomy has been greatly reduced. Dr. Joseph Price, of Philadelphia, for example, had a series of 40 cases of abdominal hysterectomy without a single death. The writer has had, within the last three years, a succession of 172 cases of abdominal section for removal of diseased uterine appendages, including quite a number of cases of ovarian tumor and of hysterectomy, with the same number of successive recoveries. With this change in the relative safety of the two methods, electro-therapeutists must be able to consider with less bias the question of operation in cases which have been found to be refractory to the electric current, or which, in the light of former experience, may be judged to be thus refractory.

A question of great practical interest is how to select cases suitable for each method of management. In the paper above referred to I presented my views on this subject as follows:—

Cases in which Electrolysis Should be Employed.—Electrolysis may be properly employed in a great majority of tumors of this class, without any considerable jeopardy to the interests of the patient, and, as shown by the results which I have tabulated, with some degree of benefit in at least 84 per cent. of all the cases treated. Keith and others report even better results. In case operative measures become necessary, no harm is done, even if no good is accomplished, provided operation is not delayed after it is clearly evident that relief is not to be obtained by other means.

Small tumors are pretty sure to be benefited by electrolysis, irrespective of the situation of the growth. There is a prospect of complete cure in interstitial growths of small or moderate size by the electrical method, and an almost equally good prospect of cure is afforded by this method in cases in which the greater portion of the growth is interstitial in character, and its size moderate. In women approaching the change of life the electrical method is especially indicated, as it has a marked effect in hastening the establishment of the menopause, the influence of which, in obliterating growths of this kind, is a matter of common observation.

Cases in which Surgical Means are Indicated.—Surgical measures employed against uterine myomata are chiefly two: First, removal of the tumor itself, or of the entire uterus and appendages; second, the removal of the uterine appendages—the ovaries and the Fallopian tubes. The first method is a procedure usually attended by greater risk of life than the second, and one which is justified only by peculiar and extreme conditions. Consulting my statistics I find that, of the fourteen cases in which electrolysis failed to accomplish material results, all but three —or 78.7 per cent.—were under 40 years of age, and 42.7 per cent. did not exceed 35 years in age. The tumors in these cases were all large and growing rapidly. The fact that these cases did not yield to the application of electrolysis, even after protracted effort, taken in connection with the remoteness of the time for the natural establishment of the menopause, and the additional fact that the menopause is in these cases often very considerably postponed, seem to me to amply justify the resort to surgical means as the only proper course to be pursued. On the other hand, the same indication for operation is present in cases in which the patient is long past the time for the proper occurrence of the menopause, the change being prevented by the presence of a large and rapidly-developing myomatous growth. The tendency of these growths to assume a malignant character in advanced age must not be forgotten, and is certainly a weighty argument in favor of the employment of radical means for their extirpation in the most prompt and thorough manner possible, when life is seriously threatened by them.

I have become thoroughly satisfied, from my personal experience in dealing with these tumors, that *growths which are subperitoneal in character are much less amenable to the influence of the electrical current than those which are interstitial or submucous.* A subperitoneal growth attached to the uterus by a narrow pedicle is out of the sphere of the electrical current, or, at any rate, of any current which can be applied with reasonable safety by the intra-uterine method or vaginal puncture.

In a case which came under my observation a few years ago, the entire uterus had been brought into the condition of a pedunculated mass by stretching of the supra-vaginal portion of the cervix, which formed a pedicle not thicker than the thumb. The patient was 63 years of age—

fifteen years past the menopause. The growth had made its appearance seven years previously, and had, within a few months, been making active development. The time the patient came under my care the uterus was fully the size of a gravid uterus at full term. The cervix, as felt by vaginal touch, was scarcely larger than a filbert, and the cervical canal was wholly obliterated. Careful bimanual examination did not enable me to determine certainly any connection between the large mass which filled the abdominal cavity and the cervix. I began the operation for removal, not knowing whether I should find a uterine or an ovarian tumor, as the mass had an elastic feeling not unlike that of a tense ovarian cyst. I found the uterus enormously and symmetrically enlarged by a soft, œdematous myoma. There was not the slightest adhesion anywhere, and the operation of removal by supra-vaginal hysterectomy was the simplest matter imaginable. The wound healed throughout its entire extent by immediate union, and the patient recovered without a single grave symptom. The tumor measured thirty inches in circumference. The treatment of this case by electrolysis, either by means of the intra-uterine electrode or electro-puncture, would have been either impossible or in the highest degree hazardous. Any attempt at electro-puncture would certainly have resulted in opening the peritoneal cavity, and possibly involved the puncture of an intestine; while an attempt to bore through the long, slender cervix would have been equally disastrous. It seems to me that a case of this sort is certainly one in which a surgical operation is not only proper, but the only proper procedure to be undertaken.

It may be said, then, that large subperitoneal growths, or growths in which the subperitoneal character predominates, should be submitted to operation, if electrolysis cannot safely be employed, or if it has been tried for a reasonable time without good results, it being provided, of course, that the case in hand is one in which the symptoms are sufficiently serious to warrant the comparatively small hazard involved in a laparotomy performed by a skillful operator under favorable conditions.

A consideration which should not be overlooked, in this connection, is the fact that in most, if not all, cases of myomatous growths of the uterus the ovaries, and often the other appendages of the uterus, are more or less diseased. Indeed, there is much ground for the supposition that the neoplasm of the uterus has its origin in some morbid influence exerted upon the organ by diseased ovaries. Not infrequently, also, the disease of the ovaries is of such character that the patient suffers far more from pain in the ovaries or other adnexæ than in the tumor itself. In these cases, are we likely to secure any great or permanent benefit from the employment of electrolysis? Indeed, is there not a possibility that, through the irritation set up by repeated cauterization of the lining membrane of the uterus, we may aggravate both the suffering and the morbid activity of the diseased appendages? I have met a number of

cases in which I was positive that this effect followed the most careful and judicious employment of the electric current. These cases seem to me to be suitable ones for surgical interference, and I do not hesitate to recommend, in cases of this sort, the removal of the appendages, which, in the great majority of cases of hard myomata of the uterus, will effect a radical cure by artificially inducing the menopause, and thus leading to the rapid shrinking and ultimate disappearance of the tumor, or, at any rate, of complete cessation of its mischievous activity.

Another class of cases in which the operation for the removal of the appendages at least is justifiable is to be found in women who are disabled by reason of the great size of the growths, or on account of pain or hæmorrhage, and whose circumstances are such as to render it impossible for them to undergo the prolonged treatment usually necessary to secure satisfactory results by the electrolytic method. In such cases, certainly, the patient should be allowed to decide which method should be adopted.

Mode of Action of the Electrical Current.—Several questions of interest arise respecting the mode of action of the electrolytic current upon uterine fibromata. In watching the effects of the application of the current in the cases which I have treated, I have become strongly inclined to the opinion that the effect of the current upon the development of the tumor is accomplished through the destruction and plugging up of blood-vessels in the vicinity of the intra-uterine electrode, whereby the nutritive supply of the tumor is, in part, cut off, thus leading, in favorable cases, to its gradual starvation. I have frequently noticed, in cases subjected to electrolysis, a slight inflammatory reaction, in which the symptoms of phlebitis in the tumor sometimes extended to adjacent parts. A marked instance of this I have recorded in which there was a very decided and rapid decrease in the size of the tumor immediately subsequent to the attack of phlebitis, provoked by the electrolysis.

In these cases removal of the appendages, by which the influence of the ovaries and tubes is gotten rid of, and by means of which, also, the blood-supply of the uterus is diminished, is the only measure likely to exert a marked influence on the development of the tumor, unless the entire growth be removed,—an operation which, under proper circumstances, is entirely justifiable.

I have observed a number of cases in which the presence of uterine fibromata was attended by frequent attacks of pelvic inflammation, in which there was distinct evidence of phlebitis, the inflammation extending to the veins of one or both legs, and in several instances these inflammatory attacks had been followed by a marked diminution in the size of the tumor. Dr. Apostoli recognizes cicatricial contraction of the endometrium and cervical canal as one of the chief factors in the control of hæmorrhage. Is it not probable that the principal effect of this mode of

treatment upon the fibroid itself is through the plugging up and subsequent withering of the vessels of the uterus? The cutting off of a portion of the blood-supply of the growths is recognized as one of the ways in which the operation of removal of the uterine appendages checks the development of these growths. It seems rational to suppose that the same effects, obtained through the action of the galvanic current upon the blood-supply of the uterus, should be followed by a similar result.

That there is an interpolar action in the treatment of fibromata by the galvanic current is clearly evident from the effects of the current observed in the treatment of various morbid conditions which are so located that careful observation is possible, as in the case of fibroid or other thickenings in the mammæ, which often disappear as the result of percutient applications of a current of 10 to 30 milliampères, as well as by the recognized influence of the galvanic current upon exudates about the joints and other localities, as well as the exudates located in the pelvis.

Modifications of Apostoli's Method in the Treatment of Uterine Fibroids.

A number of modifications of the methods of Apostoli in the treatment of fibroids have been suggested, some of which seem to be possessed of real merit, contributing either to the efficiency of the treatment or to convenience in its application, although not materially modifying the principles laid down by Apostoli. The greatest number of modifications of the method, as outlined by its originator, have been in the material employed for the abdominal electrode. The clay electrode of Apostoli certainly possesses nearly all the virtues required for a large abdominal electrode, with very few faults. Many, with myself, have, however, met frequent complaints from patients of the great weight of the electrode, and some inconvenience is occasioned by the pains required to prevent unpleasant soiling of the person and clothing of the patient. It is also impossible to use the same electrode any considerable number of times with good results, without bestowing upon it more and better care than an ordinary office assistant is likely to give. One of the first modifications of the abdominal electrode was by Dr. Martin, of Chicago, whose ingenious device consists of a shallow, wide-mouthed vessel, over which is stretched a piece of parchment or animal membrane, the metal border being covered with rubber, and the receptacle filled with water of a proper temperature when prepared for use. I was quite satisfied with this electrode for a few weeks, but found great trouble in preventing leakage, as the membrane becomes softened and stretched by continuous maceration in warm water, and, if not protected with great care, it becomes mildewed and rotten; so that a sudden collapse while in use, with a consequent deluging of the patient, is not an uncommon accident. After a few months' experience I abandoned this electrode and made a trial of the electrode of Engelmann, of St. Louis, which consists of several

sheets of tin-foil covered with chamois-skin and sheet-lint. I found this electrode eminently satisfactory when newly made; but after a little use the tin-foil becomes wrinkled, resulting in uneven contact, and consequently pain and injury of the skin. Dr. Goelet, of New York, has obviated some of the disadvantages of the clay electrode by covering it on one side with rubber cloth and protecting the other side with sheet-lint. I have employed this plan with considerable satisfaction, but have found still the disadvantage that all electrodes which require to be moistened are likely to cause the patient to take cold by moistening the clothing, thus causing a chill by subsequent evaporation.

After many experiments with various forms of electrodes, I hit upon the idea of combining some good conducting substance with gelatin. My first experiments were made with finely-powdered graphite. I found this combination capable of meeting all the requirements of a good abdominal electrode. It adheres to the skin sufficiently without moistening, is light, clean, adhesive, a good conductor of electricity, and durable. I have often had an electrode of this sort in daily use in my office for weeks without being able to detect any material deterioration in it. I think that a greater quantity of electricity can be communicated to the patient through an electrode of this composition than through a clay electrode of the same size. I attribute this to the more perfect contact between the skin and the gelatin-graphite electrode than is obtainable with a clay electrode.

The gelatin-graphite electrode is made as follows: Dissolve 20 ounces of the best gelatin in 10 ounces of boiling water; add 10 ounces of glycerin and 2 drachms of sodium chloride; heat, and add 10 ounces of finely-pulverized gas-carbon, mixing thoroughly. To form the above mixture into an electrode, take a shallow tin pan of the size desired for the electrode. Oil the inside of the pan with vaselin. Pour in a sufficient amount of the hot mixture to cover the bottom of the pan; lay in the pan a piece of sheet-lint, cut of sufficient size to allow the edges to turn up about one-half inch around the sides of the pan; pour in some more of the mixture, sufficient to saturate and cover the lint; lay in another piece of lint a little smaller than the first, and cover this also with the mixture in the same way. A third and fourth sheets of lint may be added if necessary. Usually, two pieces are sufficient to give the desired strength. A piece of brass-wire cloth, to one corner of which a binding-post has been attached, is next laid in; add more of the mixture, if necessary, and then another piece of lint. The wire-cloth and the last layer of lint may be a trifle smaller than the electrode is desired to be. Lastly, fold the upturned edges of the first layer of lint over the back of the electrode, and apply a sufficient amount of the mixture to bind them in place. When the electrode is cold and sufficiently hardened, carefully remove from the mold. If it adhere to the mold, pour a little hot water over the bottom of the mold. If the surface of the electrode is not per-

fectly smooth, it may be polished with a hot spatula. Whenever the surface of the electrode become roughened by use, it may be smoothed in the same way. If the electrode become cracked, or its surface very irregular, it may easily be repaired by applying a little of the hot gelatin mixture and smoothing with a spatula.

The following is the formula for the gelatin and red- or white- lead electrode:—

Boiling water,	20 fluidounces.
Gelatin,	4 fluidounces.
(Mix.)	
Common salt,	2 ounces.
Glycerin,	20 fluidounces
(Mix.)	
Red or white lead,	20 ounces.
(Mix with above.)	

When white zinc is used, the quantity should be half as much in proportion to the gelatin, the other ingredients remaining the same.

I have been able to use larger currents with these electrodes than with any other form. I keep a supply in my office, of different sizes, adapted to different cases, and, after having employed them for more than three years, am more and more satisfied with the results obtained. Whenever an electrode becomes worn, or its surface roughened, it is easily repaired by warming and applying a layer of the melted material. I have not had occasion to resort to the clay electrode in a single instance. I find these electrodes most useful in making applications to any part of the body in which a strong current is desired, especially in applying strong currents to the central nervous system.

For vaginal applications in which large currents are employed,—and these are necessary to secure the absorption of exudates,—I use the same material wrapped about a ball electrode. A smooth, round electrode is easily obtained by wrapping tightly around the ball a piece of lint saturated with the melted material and afterward repeatedly dipping in the material, turning while cooling so as to secure an even distribution of the material. With this electrode I have used 100 to 140 milliampères five to ten minutes without injuring the mucous membrane, and am certain that larger currents may be used if required. The electrode is wrapped with absorbent cotton or sheet-lint saturated with a solution of soda when the positive pole is used, and a weak solution of acetic acid when the negative pole is employed, so as to destroy the polar action, the interpolar effect being the action desired. The only disadvantage I find, in the use of this electrode for vaginal applications, is the fact that a new one is required for each patient. This must be true, however, of any other form of electrode made of absorbent material.

Some useful modifications have also been suggested for the active electrode used by the intra-uterine or the puncture methods. The intra-uterine electrode of Dr. Martin or McIntosh has certainly the advantage

of being more easily introduced than the rigid platinum or carbon electrodes of Apostoli, but has the disadvantage of being difficult to keep thoroughly aseptic. The insulating material softens when brought in contact with carbolic acid, and, of course, will not stand the boiling temperature, and the platinum is quickly destroyed by corrosive-sublimate solutions. The spirally-wound platinum wire soon becomes slightly loosened, affording an excellent opportunity for the collection of septic material, thus rendering the use of antiseptic solutions very necessary. I have found no satisfactory method of disinfecting these electrodes as ordinarily constructed, but have overcome the difficulty by having constructed an electrode which consists of a rigid nickel-plated staff six inches in length, graduated, and carrying at its distal end a copper wire covered with a platinum wire spirally wound, as in the Martin electrode, and with a hard-rubber tip at the extremity. A portion of an ordinary gum-elastic catheter of proper length is slipped over it, just such an amount of conducting surface being exposed as is desired for the particular case. The electrode carries two sockets with binding-screws, the purpose of which will be explained in a succeeding paragraph. After use the gum-elastic catheter is removed, and the electrode may then be cleansed by boiling and immersion in a 10-per-cent. carbolic-acid solution. It should, of course, be cleansed with boiled distilled water before being brought in contact with the electrode. The advantage of using the gum-elastic catheter is that it is a cheap and efficient insulating material which can be renewed as frequently as desired, and also renders it possible to expose a greater or less portion of the conducting surface of the electrode as may be desired in each individual case.

Mention should also be made of the non-corrosible steel electrodes introduced by Dr. Goelet. Gautier has recently introduced the use of the copper sound for the intra-uterine electrode, recommending it especially for its hæmostatic and disinfectant properties. The copper salts developed in the vicinity of the electrode are both stringent and antiseptic and penetrate the tissues a great distance by cataphoresis. Goelet and others who have employed the copper electrode recommend it highly, and my own observations lead me to believe it useful. Thus far no toxic effects have been observed. Zinc has also been used for the same purpose, and has been highly recommended by Dr. Margaret Cleaves and others.

ABDOMINAL PUNCTURE.

A modification recently introduced by Dr. G. Betton Massey, of Philadelphia, consists in the puncture of the tumor through the abdominal walls by means of carefully-insulated needles used with thorough aseptic precautions. This method seems to be a modification of the Cutter-Kimball method first adopted in 1871; but the advantages of using insulated needles and employing asepsis are so great as to render safe

and practical, judging from Dr. Massey's experience, a method which has always been regarded by the profession at large as too hazardous to be safely employed, although a considerable number of cures have been reported as the result of its use by Drs. Cutter, Semeleder, Omboni, and others.

In a recent paper (May 11, 1892) Dr. Massey reported a case under treatment by this method in which 450 milliampères of current were used by abdominal puncture once a week, "without the patient losing a day from her occupation as a teacher in the public schools." The tumor in this case was a very large one. If further experience prove that this method is as safe as it seems to be in the hands of Dr. Massey, it will doubtless come to be recognized as a great advance upon the method of vaginal puncture for a large number of cases, as the risk of penetrating large blood-vessels and damaging important structures is very much less.

There are also cases in which vaginal puncture is almost, if not altogether, impracticable in consequence of the position of the tumor to which this method might be especially applicable. A tumor can be penetrated more deeply and complete asepsis can be more easily secured by abdominal puncture than by the vaginal method, and by the use of the insulated needles the superficial slough, which is a constant result in the vaginal method, is avoided. This method is certainly deserving of a careful trial in the hands of prudent men; but it must be remembered that it is a surgical procedure of too grave a character to be undertaken by a novice or a person unfamiliar with the technique of electrolytic operations and electric dosage.

THE PERCUTIENT AND VAGINAL METHODS.

In cases in which the intra-uterine applications are accompanied by great pain, some benefit may be derived from the use of my gelatin vaginal electrode already described, with which almost as large doses may be employed as with the intra-uterine electrode. Even the percutient method may not be without results, provided sufficiently large currents are employed. Onimus has shown that a continuous current applied externally, with the positive pole over the lumbar region and the negative electrode over the abdomen above the pubes, is of marked benefit in cases of scanty menstruation. A reversal of the poles ought to diminish uterine congestion, and thus, in some degree, to diminish the blood-supply of the tumor and lessen its growth. For applications of this sort a large electrode should be applied to the lumbar region, a smaller one, having an area about one-third as great, being applied over the tumor, the smaller electrode positive, the larger one negative.

It may be worth while to note just here the practical fact that, if the concentration of an electric current in the anterior half of the body is

desired, the electrodes must be proportioned in size according to the distance of the point at which it is desired to concentrate the current from the pole designed to be the active one. Two large electrodes of equal size placed upon opposite sides of the body will concentrate the current at the centre of the body, or midway between the two electrodes. If one electrode is made smaller than the other the point of concentration will be proportionately nearer the smaller electrode. In case a very small electrode is used on one side and a very large electrode on the other, the point of greatest concentration will, of course, be very superficial. Practically, it may be said that the point of greatest concentration, when electrodes of considerable size are used, will be found at the point of intersection of diagonal lines connecting opposite corners of the electrodes when so placed that their centres are opposite.

It should be borne in mind that in the employment of the percutient method, or when abdominal and vaginal electrodes are used, only the interpolar action of the current is utilized, and hence the results obtained, if any, must be waited for with much patience.

COMBINATION OF THE SINUSOIDAL WITH THE GALVANIC CURRENTS.

In cases in which the galvanic current causes great pain, a tolerance may be established by a preliminary application of the faradic or sinusoidal current to the uterus, or by a simultaneous employment of both the galvanic and faradic currents. For this purpose I use an intra-uterine electrode with two binding-screws at its outer extremity, to one of which is attached one rheophore of a sinusoidal apparatus, the other being connected with the galvanic circuit. The sinusoidal circuit is completed by a third electrode applied to the lumbar region. The sinusoidal current employed is one of high tension. I have employed for this purpose the secondary current, obtained from a bobbin wound with two hundred feet of No. 36 wire, the exciting current being furnished by an alternating arc-light dynamo, and purely sinusoidal in character, the alternations being very rapid—nearly 17,000 per minute.

The properties of this current, which are truly remarkable, will be dwelt upon in another paragraph. If an ordinary faradic current is used, a current of the highest attainable tension and with the most rapid interruption possible secures the best results; but the results of such a current are much inferior to those obtainable from a sinusoidal apparatus. The induced current should be applied for five minutes before the galvanic current is turned on, being gradually increased as tolerance is established. I consider this combination of the two currents in the treatment of fibroids a modification of considerable importance, as it greatly increases the tolerance for the galvanic current and at the same time lessens the after-irritability and tendency to inflammatory reaction.

ACTION OF GALVANIC CURRENT UPON THE ABDOMINAL SYMPATHETIC IN THE TREATMENT OF UTERINE FIBROMATA.

The notable improvement in the general health of patients treated by the electrolytic method, which has been remarked by so many observers, must be attributed, in part at least, to the influence of the galvanic current upon the abdominal sympathetic. The large ganglia of the abdominal sympathetic come within the sphere of the influence of the current when it is applied in the usual manner, and must be favorably influenced thereby. I witness constantly great benefit from the use of the galvanic current applied with a large electrode over the abdomen and one of equal length, but narrower, over the spine opposite. For a number of years I have been in the habit of applying currents of 30 to 80 milliampères in this manner, and with most excellent results as regards improvement in general health and relief of various disorders of the digestive organs.

PRELIMINARY SURGICAL TREATMENT.

One of the most embarrassing circumstances connected with this mode of treatment in many cases, and one which is frequently a source of very great discouragement to patients, is the fact that at the beginning of treatment there is very likely to be considerable increase of hæmorrhage. My observation has been that, in nearly all cases in which hæmorrhage is the leading symptom, extensive vegetations of the endometrium are found to be present. These may be destroyed by means of electrical treatment perseveringly employed, but may be removed at once by use of the curette, a surgical measure attended by little or no risk when employed in connection with the proper asepsis. It has for several years been my custom to begin the treatment of a case in which hæmorrhage is a prominent symptom by a thorough curetting of the uterine cavity, and I have not infrequently removed half a handful of vegetations which it would have required at least two or three months to destroy by the electrolytic method, long before the expiration of which time I should probably have lost my patient, in consequence of the failure of the treatment to materially lessen, even if it did not actually increase, the hæmorrhage.

The destruction of masses of vegetations within the endometrium by electrolysis, which must necessarily leave behind, in some cases at least, a considerable amount of decomposable *débris*, is frequently followed by a febrile reaction, as indicated by a rise of temperature with increase of pain, in some instances, besides symptoms of an extension of the inflammation of the surrounding structures. There certainly can be no objection to the use of the curette in these cases, and that it shortens the treatment by a very considerable period is beyond question. I have been led to the adoption of this modification of the method employed by Dr.

Apostoli, as the result of the careful observation of a considerable number of cases, amounting to nearly two hundred in all, and have never recognized even the slightest suggestion of injury or danger arising from this combination of surgical and electrical means.

I am certain that a great saving of time can often be made by this means; and it seems to me that one should not be deterred from its employment by a desire to determine with the greatest possible exactness the therapeutic value of electrolysis. The patient's interest must be considered first. The interest of scientific investigation must not stand in the way of the employment of any measure that will expedite the patient's recovery.

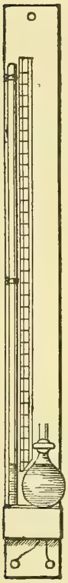
Fig. 1.

THE COULOMBMETER.

Still another modification which I have introduced into my own practice, and which is, perhaps, worthy of mention, is the employment of the coulombmeter. It is, perhaps, unnecessary to explain to the readers of this volume that the coulomb is the standard unit of measure of electrical work. I have made use of the coulombmeter for more than four years. A simple form of coulombmeter is shown by Fig. 1. This instrument, which was constructed by my electrician, working under my instruction, determines the amount of electrical work done by the measurement of the oxygen and hydrogen produced in the decomposition of water. The instrument I have in use registers 120 coulombs, which represent as much electrical work as is ordinarily done at one *séance*.

Placing the coulombmeter in the circuit with the milliampèremeter and the patient, one can readily measure not only the strength of the current as determined by the milliampèremeter, but also the actual amount of the electrolytic work done during the *séance*, as shown by the reading of the coulombmeter. I have found the proper dosage, as regards the number of coulombs employed, to be from 50 to 120 coulombs.

In administering the treatment I take no account of the time of the *séance*, but only of the reading of the milliampèremeter and the coulombmeter, giving the patient, as a rule, as much current as can be endured without excessive pain, and continuing the application a sufficient length of time to produce the number of coulombs which I judge to be the proper dose for the case in hand.

I do not wish to be understood as intimating that a given number of coulombs represents exactly the amount of work accomplished in the tissues irrespective of the strength of the current, as one might suppose would be the case. I have made a number of experiments on animal tissues of various sorts, both alive and dead, and find that while there is

a definite relation between the number of coulombs developed during the *séance* and the amount of work done in the tissues, the latter is also influenced very materially by the strength of the current employed. Nothing could be more erroneous than the supposition that the same result will be produced by a current of 50 milliampères applied for ten minutes as by a current of 100 milliampères applied for five minutes. This supposition is true as regards the number of coulombs shown by the coulombmeter, but the vital resistance of the tissues is a factor which materially modifies the result when the current is applied to the animal body. The vital strength of the tissues is a variable factor which cannot be exactly measured by either the coulombmeter or the milliampèremeter.

It is not claimed that the coulombmeter furnishes a means by which exact equivalents in dosage may be secured for patients exhibiting marked difference in tolerance to the current, but it is evident that, by the combined employment of the coulombmeter and the milliampèremeter, a more near approach to exactness in dosage may be secured than by the mere use of an ordinary time-piece; although, of course, the number of coulombs may be determined by a mathematical calculation when the amount of current and the length of the *séance* is known. The coulombmeter, however, saves the time and annoyance of the calculation by showing at a glance the amount of electrical work done. The fact that the amount of actual work accomplished in the tissues is less with a current of 20 ampères than with a current of 100 ampères, although the length of the *séance* in which the lesser current employed may be such as to render the number of coulombs the same, is one of practical value, since patients who tolerate the current badly require small doses, as regards the total amount of current employed, as well as with reference to the volume of the current.

Another advantage afforded by the coulombmeter is, that in case of necessity it may be made to replace the milliampèremeter—temporarily, at least—in the hands of an expert. It is only necessary to note the number of coulombs produced by the current and the length of the time required therefor, when, by simple calculation, the number of milliampères of current employed may be easily and accurately determined. For example, suppose 10 coulombs of the current are obtained in one hundred seconds, we have only to divide the number of coulombs by the number of seconds to obtain the number of ampères. Multiply by 1000, and we have the number of milliampères, which in this case would be 100. The coulombmeter which we have described above is not expensive, and can be constructed by any instrument-maker. After several years' use, I should very much dislike to be compelled to dispense with the instrument. It is certainly a convenience, if not an absolute necessity, in electro-therapeutics.

THE AFTER-CARE OF PATIENTS TREATED FOR UTERINE MYOMATA.

I feel certain that some of the failures which have been attributed to the electrolytic method of treating uterine fibroids have been due to neglect of proper care of patients subsequent to the application of the current rather than to the method employed.

The after-treatment of these cases is a matter of no small consequence, but one which seems to have received little consideration. I know a number of gynæcologists who allow their patients to travel several miles in a cab, a street-car, or on the railroad after an application of electrolysis, irrespective of the weather or the season of the year. My custom is to require patients, who have received an application of electrolysis, to assume at once a horizontal position, and to retain it at least a greater portion of the time for the next twenty-four hours. A hot vaginal douche of boiled water, or water containing 1 part of mercuric bichloride to 10,000 of water, is employed immediately after the treatment, and twice each day for a few days following. In case there is a tendency to hæmorrhage after the treatment, a mixture consisting of equal parts of alum and subcarbonate of bismuth is applied to the cervix, and held in place by a few pledgets of cotton or wool. By the employment of careful precautions against hæmorrhage, the occurrence of this disagreeable symptom, which not infrequently attends the beginning of a course of treatment by electrolysis, may usually be prevented. I have thus been able to treat cases which had been declared by other gynæcologists to be unsuited to this treatment, after they had made unsuccessful efforts for several months.

For more than three years I have had in use another instrument, which consists of a double cannula, intended to be applied to the cavity of the uterus. The uterine end of the instrument consists of a metallic chamber, the inner cannula reaching only slightly past its centre. The rest of the instrument is insulated with hard rubber. By means of a fountain syringe and suitable connections of rubber tubing the metallic chamber may be given any desired temperature, from near the freezing point to 200° F., by a current of water passed through it. The degree of heat may be regulated so as to simply coagulate the tissue-fluids and shrivel the vessels, or to produce a real caustic effect, devitalizing vegetations and destroying the varicose vessels of a diseased endometrium. It acts also as an efficient and penetrating disinfectant. I believe that this agent alone may be successfully employed in the treatment of some forms of uterine myomata. It is certainly a safe and efficient means of controlling hæmorrhage.

In obstinate cases which yield very slowly to treatment I do not hesitate to employ ergotin in efficient doses, hydrastis, and other remedies of recognized value in lessening the blood-supply of the uterus and its appendages. It is true that, by the combination of surgical and

medicinal with electrical treatment, it is not possible to form an absolutely exact opinion respecting the precise value of each remedial agent in securing the results obtained, but any different course places the physician in the attitude of a scientific investigator who is willing to sacrifice to some extent his patient's interests for the advancement of his researches. However justifiable such an attitude may be in hospital practice, I have not been able to convince myself that it is the proper plan to pursue in the treatment of private cases, who rightfully expect their physician to secure the most complete and speedy recovery possible, irrespective of any personal interest he may feel in the scientific differentiation of therapeutic values.

ACCURACY IN DIAGNOSIS REQUIRED.

As regards the safety of the electrolytic method of treating uterine fibromata, I am certain that all who have had any extensive experience with this remedy will agree with me in deprecating the wide currency which has been given to the idea that the method is innocuous, and that its employment requires only a very small knowledge of electro-therapeutics and only sufficient proficiency in gynæcological diagnosis to detect the presence of a foreign mass in the pelvis. The remedy is a safe one in the hands of an expert. Rope-walking is safe enough for a professional in this line, and an experienced pilot guides the huge ocean steamship into New York Harbor by a method which is eminently safe in his hands and with his knowledge, but which would almost certainly lead to destruction of life and property in the hands of a novice. The mistaking of an ovarian cyst or a pyosalpinx for a fibroid tumor, through an error in diagnosis, may lead to fatal results. A case came to the knowledge of the writer three or four years ago, in which either a pyosalpinx was mistaken for a uterine fibroid or was overlooked in the examination, and with the result that the patient died from rupture of the pus-sac into the peritoneal cavity, during an attack of inflammation following an application of current only 40 ampères in strength, and lasting but five or six minutes.

In a case which came under the writer's care in 1891, a patient who was suffering from an abdominal tumor which had been supposed to be a uterine fibroid had been treated by the electrolytic methods, a reasonable amount of care having been apparently employed in the treatment, and yet the result had been extensive peritonitis and a rapid increase in the growth. Upon opening the abdomen I found an immense multilocular cyst which filled the entire abdomen, crowding up against the diaphragm ; the tumor was adherent to the abdominal walls throughout its whole anterior aspect, the adhesions extending down deep into the pelvis, from which point the inflammatory action had evidently originated. The patient fortunately made a good recovery, but two or three more electrolytic applications would probably have produced a fatal

result. In another more recent case, which came under my care after having been submitted to electrolytic treatment, I found a fibroid tumor of considerable size reaching far above the umbilicus, with evidence of extensive disease of the appendages, which had been greatly aggravated by the electrical treatment, each application being followed by severe pain and inflammatory reaction. Considering further attempts in this direction useless, I performed a hysterectomy, removing both the uterus and the greatly-diseased appendages by the abdominal method. This patient also made a good recovery.

These cases are mentioned simply as illustrations of the fact that the treatment of uterine fibromata by means of electrolysis is not a procedure by any means devoid of risk, and in the writer's opinion it is a method of treatment which should be considered at least as equal in gravity to the operation of curetting the uterus, and one which should be surrounded with just such precautions as regards diagnosis, asepsis, etc., as would be employed in connection with the operation of curetting the endometrium or repairing a lacerated cervix.

I am certain that cases of this sort can be much more satisfactorily treated in a hospital than in office practice. It is true that in many cases patients suffer little or no pain nor inconvenience after applications in which currents of considerable volume have been employed; nevertheless, there are so frequent exceptions to this perfect tolerance of the current that it is far better to adopt, as a uniform rule, the requirement of absolute rest for at least several hours immediately after an application of a current has been made.

Before undertaking the treatment of a case of uterine fibromata by means of either vaginal or abdominal puncture, one ought to satisfy himself very thoroughly that the case is one which will not ultimately require a hysterectomy or a removal of the appendages. This fact is sufficiently emphasized by the statements of Apostoli that the seven cases treated by him, which were subsequently operated on by six different eminent surgeons of Paris, all died as a result of the operation. But in the seven cases in which I have myself operated subsequently to the unsuccessful employment of electrolysis, once for hysterectomy, in six cases for the removal of the appendages, the patients all recovered; but I apprehend that recovery would not have been the result in some of the cases, at least, if the puncture method had been employed. This remark is not made for the purpose of condemning treatment by vaginal puncture, although I have myself ceased to employ this method, but only to emphasize the importance of a careful scrutiny of the case before the beginning of this mode of treatment, which certainly places serious complications in the way of any future surgical interference, and to secure also a careful forecast as regards the probable rather than the possible results.

The Treatment of Pyosalpinx by Galvano-puncture.

This procedure, one of the more recent of Dr. Apostoli's additions to electro-therapeutics, has, I think, been received with very much less favor than the same method employed in the treatment of fibroids. The results reported by Apostoli and others who have employed this method show clearly that, while cases of pyosalpinx may be brought to a successful termination by its use, it must be considered as something of a question as to whether this is the best method of dealing with this form of pelvic disease, when we consider, on the one hand, the long time required for the completion of a cure by the method of galvano-puncture and the constant menace to the patient through an exaggeration of inflammatory activity and the possible infection of surrounding structures by aseptic absorption, and then recall, upon the other hand, the small mortality which attends the complete removal of the diseased structures in cases of this sort, when patients are able to avail themselves of the services of expert abdominal surgeons. I think it must be regarded as questionable whether it is not far better to employ the radical rather than the palliative method. There are, certainly, cases in which a pelvic abscess is better treated by simple puncture than by any attempt at ablation of the diseased structures; and in cases of this sort an electro-puncture may be regarded as an efficient means of securing a proper outlet for the pent-up pus. But may not the same advantage be claimed for the galvano-cautery, the Paquelin cautery, or similar means? It has been my practice for a number of years to employ the Paquelin or galvano-cautery in opening abscesses of this sort whenever practicable, and I believe this method preferable to electrolytic puncture.

As regards a class of cases in which the removal of the appendages is admissible, it may be argued that the method of galvano-puncture is one which may be employed by physicians not versed in abdominal surgery. From what I have seen of this method of treating pyosalpinx, I feel compelled to the conclusion that fully as much tact, judgment, and skill are required to conduct to a safe termination a case of pyosalpinx by the galvano-puncture method as is requisite for the successful removal of the appendages by laparotomy.

Dr. Goelet, of New York, has devised a new form of electrode to be employed for galvano-puncture in cases of this sort, which seems to considerably lessen the risks at the time of operation and the danger of subsequent aseptic infection of the system. Dr. Goelet also reports the successful evacuation of pus-tubes in a number of instances by the application of the negative pole to the cornua of the uterus by the intra-uterine method, recording a number of cases in which this has been accomplished in the *New York Medical Journal* of June 8, 1889. It is difficult to form an estimate of the value of this mode of treatment. I feel somewhat uncertain as regards the true value of this mode of procedure for the

relief of pyosalpinx, but, judging from the condition of the structures which I have not infrequently noticed in operations for removal of pus-tubes, I cannot but consider the method somewhat dangerous. Not infrequently the occlusion of the tube is some little distance from the uterus, an isthmus of small and healthy tube connecting the point of occlusion with the cornua of the uterus. To undertake to enlarge the calibre of the Fallopian tube for an inch or two by means of an intra-uterine electrode with a current of 100 milliampères seems to me to be a somewhat hazardous proceeding. I should, myself, much prefer opening the abdomen and removing the diseased structure entire. Even if the Fallopian tubes were not punctured, thus opening up the peritoneal cavity, an inflammation might easily be set up, in consequence of the contiguity of the purulent mass and the infection of the peritoneal tissues in the neighborhood, and thus the condition might be excited and already-existing adhesions be made more extensive and dense.

Even if a pus-tube should be successfully treated by galvano-puncture, either vaginal or intra-uterine, there is left behind diseased structures, which may be properly compared to a mass of inflammable or explosive material, and which only waits favorable conditions for an active combustion or a violent explosion.

Still more questionable, in the author's opinion, is the treatment of diseased ovaries by the method of electro-puncture. It is true that the galvanic current thus applied may set up inflammatory processes which may result in a complete cicatrization and degeneration of the diseased structures, but the process will necessarily be a slow one, and, as it seems to the writer, quite as likely to end disastrously as otherwise. Nevertheless, it is but fair for me to state that, as regards the use of galvano-puncture in the treatment of diseased appendages, I have had no other experience than that obtained by observing cases treated by Professor Apostoli and others, as I have myself never employed galvano-puncture except in the treatment of uterine fibroids.

The Undulating Galvanic Current.

Not knowing with certainty that I am adding anything new to the researches of electro-therapeutics, I venture to mention a modification of the galvanic current, in which the volume of the current is alternately increased and diminished, thus producing a sort of undulating or wave-like modification of the current, without change in polarity. I believe that by this means the effect of the current upon tissue metamorphosis may be intensified, and that possibly a current of this sort may induce what may be termed vasomotor gymnastics, through the alternate contraction and relaxation of the muscular coats of the blood-vessels. The differential value of this current, as compared with a continuous current of maximum strength, may be similar to that existing between the repeated movement of a muscle acting upon a light weight and a prolonged

action of the muscle acting upon a heavy weight. There can be no question that the nutritive processes by which a muscle is made to increase in strength are better excited by repeated movements of moderate intensity than by a single exhaustive effort. It is certainly reasonable to suppose that the continual change in the electro-tonic condition of the tissues, produced by a current of the sort described, must result in a coincident reaction of the nerve-elements, and perhaps other vital structures of the parts to which the current is applied. The current described I produced by connecting a Bailey rheostat with a crank movement, by means of which the carbons are moved up and down in the liquid, thereby continually changing the resistance in the circuit, and so modifying the current.

The Fluctuating Galvanic Current.

Dr. H. G. Piffard, of New York, has recently described a method of producing a fluctuating galvanic current which is worthy of notice. It consists simply in placing an ordinary faradic apparatus in shunt with the current. Each time the circuit is closed by the rheotome the current will be increased, or diminished each time the circuit is opened. The effect of this rapid fluctuation in the current is to produce muscular contraction resembling that caused by a strong faradic current; but this current is, of course, capable of acting upon muscles which cannot be made to respond to the faradic current. I have also found this current useful, by internal application through a stomach electrode, in cases of dilatation of the stomach.

The Alternating Galvanic Current.

Excluding the specific effects of polarity, similar, and perhaps more intense, effects may be produced by the employment of a commutator so constructed as to rapidly change the direction of the current. Five years ago I had constructed a pole-changer, actuated by clock-work, by means of which rapid reversals of the current could be secured. Recently the Kidder Company have constructed an ingenious device by which extremely rapid alterations of the current may be secured.

Recent Studies of the Faradic Current.

Since Duchenne demonstrated the differential properties of the current produced by the first and second helices of an induction apparatus, a difference in the physiological effects of the several currents produced by a faradic machine supplied with several bobbins has been recognized by practical workers in electro-therapeutics, although there have been those who disputed the existence of the differences referred to, owing to the want of a ready physical explanation of such a difference. That this difference is not due solely to differences in tension was clearly demonstrated nearly half a century ago by the experiments of

Duchenne, who took care to equalize the several currents compared before testing their physiological effects. By comparing the direct extra current of the two primary coils, one composed of 3000 feet of wire $\frac{1}{150}$ inch thick and the other 600 feet of wire $\frac{1}{25}$ inch thick, the properties peculiar to the longer, fine wire were found to be absent, but at once appeared when the current was induced by a helix of thick, short wire.

That there is a real difference in the physiological effects of currents produced by wires of different lengths must be considered as a fact established by wide and careful examination, although an explanation of the phenomenon cannot be easily offered. Duchenne's experiments showed that a current of the first helix, when compared with that of the second helix,—in other words, the current from a coil of coarse and short wire, when compared with a coil composed of fine wire of great length, —excites more acutely the sensibility of subcutaneous organs,—the nerves, muscles, rectum, bladder, testes, etc.,—increasing the contractility of the muscles; while the current of the second helix, or the coil of finer and longer wire, acts especially on the cutaneous sensibility, and penetrates more deeply into the tissues. The current obtained from the coarser coil he found to be more easily localized in its action.

Dr. Apostoli lays great stress upon the differential properties of induced currents of different tension, and his observations upon this subject have been amply verified by many observers. The advantage of the longer and finer wire as a means of relieving pain, through stunning the nerves of the part to which it is applied, is quite in harmony with the observations of Duchenne respecting the influence of high-tension currents upon cutaneous sensibility. Apostoli does not, however, so far as I am aware, recognize any difference between the two poles of the faradic current. That there is a marked physical difference between the two poles must be admitted by a consideration of the facts in relation to the induced current furnished by electro-physics. Bardet has shown that the duration of the inverse or closing current is 0.0114 of a second, while that of a direct current, or current of opening, is only 0.0042 of a second, a period only about one-third as great; while the energy of the direct or opening current is nearly six times as great as that of the inverse current,—a fact which may be easily verified by observing the effects of the two currents upon the needle of a suitable galvanometer. The extra current of the primary coil being in opposition to the inducing current weakens it, while the direct or open current being in the same direction as the exciting current is strengthened by it; hence, the effect produced by opening the circuit must be chiefly at the negative pole. This, evidently, is the reason for the greater irritating effects of the negative pole of the faradic current, it being clear that the effect of the extra current, in weakening the primary current, must also result in lessening the strength of the inverse current in the induction coil, while producing the opposite effect upon the direct current. This

PLATE I.

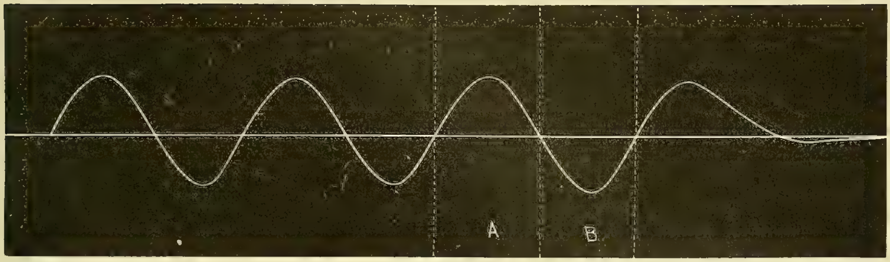

FIG. 1.—Graphic Representation of the Sinusoidal Current Obtained from a Magneto-Electric Apparatus Employed by the Author since 1883.

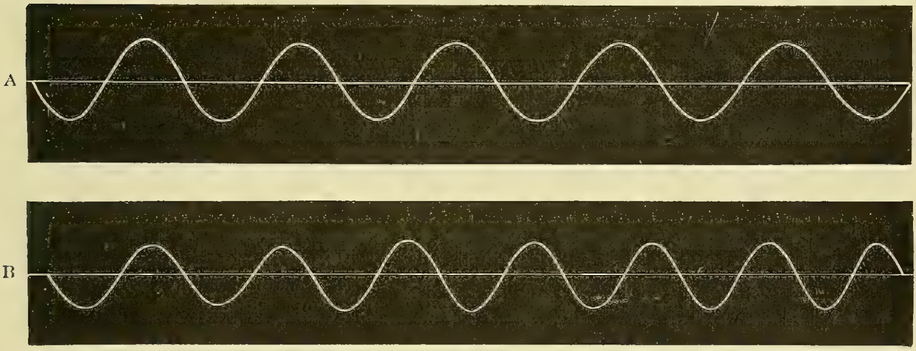

FIG. 2.—Tracings Produced by Current from Magneto-Electric Apparatus Recently Completed by the Author. A, current from armature; B, current from outer coils.

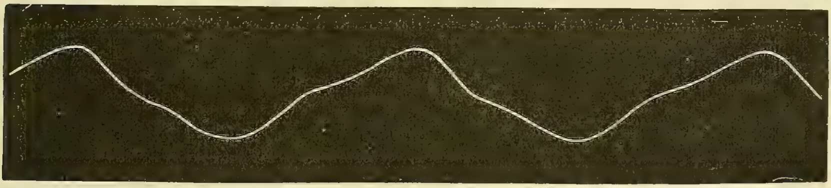

FIG. 3.—Representation of a Magneto-Electric Current Not Sinusoidal in Character.

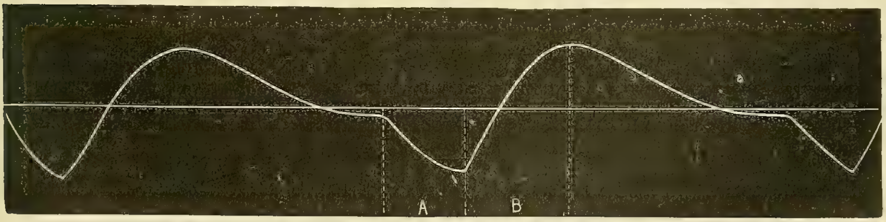

FIG. 4.—Slowly Interrupted Current from a du Bois-Reymond Coil. A, make; B, break.

PLATE II.

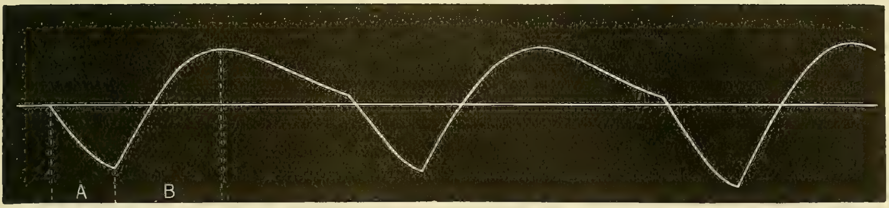

FIG. 1.—More Rapidly Interrupted Current from a du Bois-Reymond Coil. A, make; B, break.

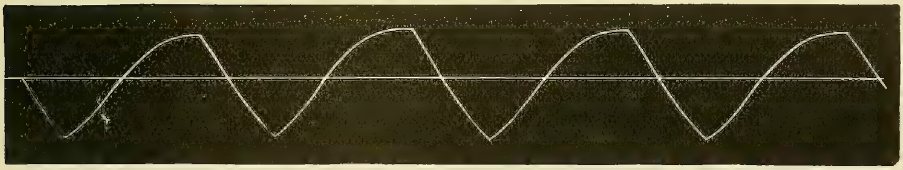

FIG. 2.—Current from the same Apparatus Still More Rapidly Interrupted.

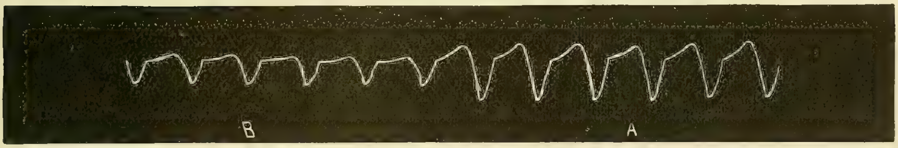

FIG. 3.—A, Current from du Bois-Reymond Coil. B, Current from the same Apparatus and same Adjustment, but with Weaker Exciting Current.

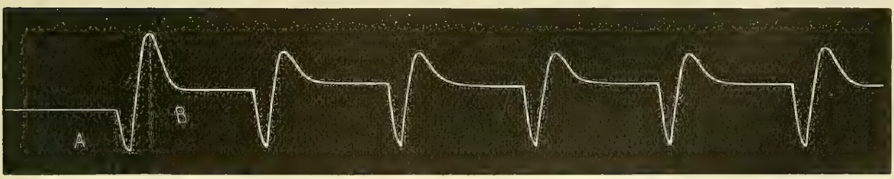

FIG. 4.—Current from Faradic Apparatus (McIntosh). A, make; B, break.

PLATE III.

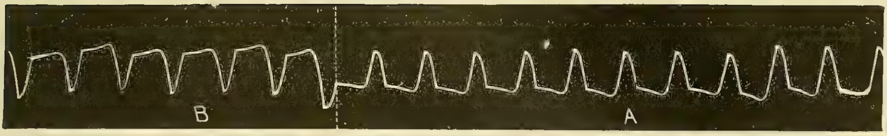

FIG. 1.—A, Current from Faradic Apparatus (McIntosh), same as Fig. 4, Plate II, but with Different Adjustment of the Rheotome. B, Current Reversed.

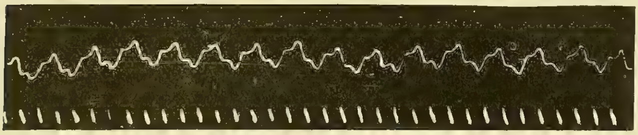

FIG. 2.—Fluctuating Current. Intervals indicated by time markings represent $\frac{1}{280}$ second each.

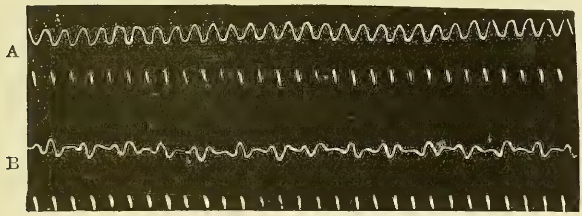

FIG. 3.—A, Current from Coil Excited by Thompson-Houston Arc-Light, alternating 16,800 times per minute. B, Current from Secondary Coil of Ordinary Faradic Apparatus Excited by Alternating Current. Time markings represent intervals of $\frac{1}{280}$ second.

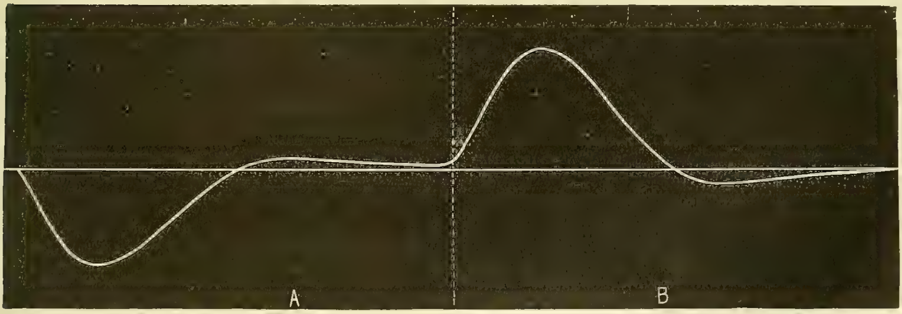

FIG. 4.—Curves Obtained by Making and Breaking the Current from an Ordinary Induction Coil without a Rheotome. A, make; B, break.

fact is one which, perhaps, ought to receive more consideration than it has heretofore had in the therapeutic use of the faradic current, although the observations upon which it is based are by no means new.

It is possible to weaken the extra current by lessening the number of turns in the primary spiral; and Helmholtz has accomplished the same result by introducing a secondary current into the primary circuit, so that the current of the primary spiral never completely disappears, the breaking and closing of this secondary circuit having the effect simply to weaken the primary.

The faradic current is not only an alternating current, but is also a broken current. This fact adds very greatly to its irritating properties, as manifested by its effect upon the muscles. This is also the cause of the irritating effect upon the nerves of cutaneous sensibility.

The graphic study of the current produced by a faradic machine shows very clearly the fluctuating and uncertain character of this form of electricity. The current produced by a faradic machine is subject to a continual modification from variation in the strength of the actuating battery and in the adjustments of the rheotome, as is well shown by the tracings which I present with this paper (Plate I, Fig. 4; Plate II, Figs. 1, 2, 3, 4; and Plate III, Figs. 1 and 4). I have made a large number of tracings of the currents produced by various forms of faradic apparatus, and under various conditions, and have made some experimental attempts with a view of securing an improvement upon the ordinary form of induction apparatus, but I have thus far met with little encouragement of success. I believe the faradic machine is inherently faulty as a scientific electrical apparatus for medical purposes. The rheotome is a fatal element of weakness, changing the character of the current with the slightest modification, and often, as every electrician knows, in a manner which, if the thing were intelligent, must be regarded as purely whimsical.

The invention of Faraday answered an excellent purpose during the embryonic period of electro-therapeutics; but now that we have learned the value of the milliampèremeter, the voltameter, and the coulombmeter, and have acquired methods of precision in our electro-therapeutic procedures, the faradic battery, like the shocking machines of half a century ago, must give place to a more precise and reliable instrument. The effort to overcome the weaknesses of the induction coil by the provision of some means of measuring the current obtained from it is a task as useless as it is difficult, since nothing else than a graphic representation of the currents produced by it could enable a practitioner to regulate the machine twice alike, and such a method of regulation would be altogether too cumbersome and dangerous for practical use.

In the group of tracings shown herewith, which are intended to illustrate the effects of changes in the rheotome (Plate I, Fig. 1; Plate II, Figs. 1, 2, 3, 4), no change whatever was made in the apparatus,

except such as results from turning slightly in or out the adjusting-screw of the rheotome. The increased or diminished amplitude of the curves produced are an indication of the changes in potential of the current resulting from the changes referred to. There seems to be no method by which fluctuation in the character of the current can be remedied, and consequently the faradic machine, in the opinion of the writer, must sooner or later be recognized as too rude an appliance to be of value in scientific electro-therapeutics, or, at least, to be of use only in a limited class of cases in which mere excitation is the object to be accomplished. Dr. George J. Engelmann, of St. Louis, has recently introduced a modification of the ordinary faradic apparatus somewhat lessening the irregularity of the current by employing a separate current to operate the rheotome. This improvement is unquestionably a valuable one, but it does not prevent the fluctuation of the current due to the rheotome, —a difficulty which the writer believes to be incurable.

The Sinusoidal Alternating Magneto-Electric Current.

In a series of experiments first undertaken ten years ago (1883) with different forms of batteries and electrical machines, I obtained a magneto-electric machine constructed in such a manner as to give a sinusoidal alternating current. When run at its maximum speed, this apparatus is capable of overcoming a resistance of 20,000 ohms, producing half an ampère of current. I found, in my experiments with this machine, that it possessed the remarkable property of producing painless muscular contractions, the frequency of which could easily be regulated by controlling the speed of the machine. When run at a high rate of speed, the current, controlled by the rheostat, was found to be remarkably smooth and pleasant in application, and was much less active in exciting cutaneous irritability than an ordinary faradic current. I have had this apparatus in use the greater part of the time for more than ten years, and have been exceedingly pleased by its performance.

I first described this current in a paper read before the American Medical Association in 1888.

In concluding my description of the current, I stated as follows: "The therapeutic results following the use of this current justified me in claiming for it a decided superiority over any other form of electric current for this purpose (that of exciting muscular action). I have used this current for medical purposes for the last five years." In the following year I described the current again in a paper read before the American Association of Obstetricians and Gynæcologists. The publication of d'Arsonval's graphic representations of currents of regular and irregular variation led me to undertake a similar study of the current produced by the electro-magnetic apparatus to which I have referred. Although recognizing the peculiarity of the current which I had discovered, and which had led me to utilize its therapeutic properties for a number of

years, and with excellent advantage, I was quite at a loss to understand its peculiar qualities. I showed the machine to Dr. E. Betton Massey, of Philadelphia, and other medical electricians, who, like myself, were struck with its peculiar properties, but were unable to explain the reason of its peculiarities.

In order to obtain a tracing of the current, I improvised an electrograph by attaching a writing lever to the solenoid of a large and very delicate galvanometer. The curve which I obtained by this means encouraged me to persevere. I accordingly undertook to make a more delicate machine, the construction of which, although different from that of d'Arsonval's, was suggested to me by the description of his apparatus. The construction is as follows :—

A, *B*, *C*, and *D*, Fig. 2, represent the several portions of a soft-iron

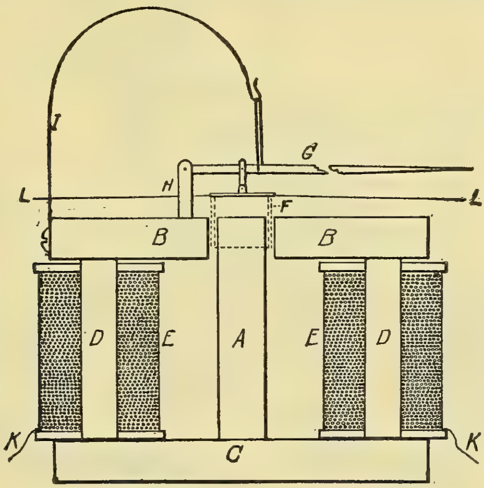

FIG. 2.—SECTION OF THE ELECTROGRAPH.

frame. On the two arms, *D* and *E*, are mounted two solenoids, *E E*, each wound with 106 feet of copper wire of the diameter 0.032 inch. The two solenoids are connected with the poles of a battery, thus producing an electro-magnet, of which *A* constitutes one pole, and *B B* are semicircular at their ends, so as almost completely to embrace the arm *A*, thus producing an annular magnetic field. A small solenoid composed of 10.5 feet of very fine copper wire (0.005 inch in diameter) is placed at *F*. The current to be tested is passed through this solenoid by making proper connections with the terminals, *L L*.

When a current is passing through the coils *E E*, thus producing a magnetic field about the solenoid *F*, a current flowing in one direction through *F* will cause it to be lifted up, while a current passing in the opposite direction will cause it to drop below the level to which it is held by the spring *I*. The writing-arm *G* is attached at one end to the brass

post *H*, the other end being free. A small standard connects it with the solenoid *F*, which, acting upon the short arm of the lever, produces, even with a very slight movement of the solenoid, a considerable movement of the long bamboo lever, the free end of which rests against the smoked surface of a revolving cylinder.

By means of this device the most delicate variations in an electric current may be instantly recognized and recorded by means of a kymographion, in the same way in which tracings are taken from a recording tambour (Fig. 3).

By means of this instrument I have taken a large number of tracings

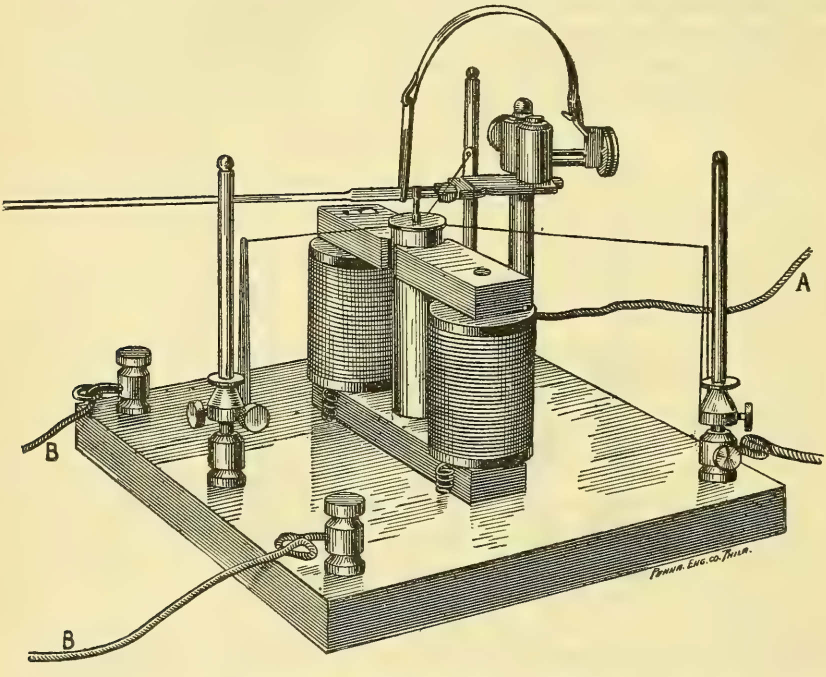

FIG. 3.—THE ELECTROGRAPH. (Kellogg.)

of different forms of electric currents. Being especially interested in the sinusoidal current, I naturally first gave my attention to this, and obtained the tracing shown in Plate I, Fig. 1.

The physiological effects produced by the sinusoidal current which are most characteristic of it are (1) its painlessness and (2) its great penetrating power. D'Arsonval has shown that the intensity of the motor or sensory reaction produced by a given current is proportional to the variation of potential at the point excited. The constant alternation of the current prevents polarization of the tissues acted upon, and hence maintains the maximum exciting effect.

That important physiological significance must attach to the *mode*

of variation in potential as well as to the *amount* of variation is clearly evidenced by the difference in the effects occasioned by the gradual or sudden withdrawal of the current in making an application of galvanic electricity, which is familiar to all medical electricians.

I have recently constructed an apparatus for giving a sinusoidal current (Fig. 4), producing two currents differing in physiological effects. The apparatus consists of a permanent magnet, between the poles of which an armature revolves, while a coil with a soft-iron core is connected with each pole upon the outside. The changes in the condition of the soft-iron core produced by the revolutions of the armature give rise to an induced current in the external coils, of higher potential than that obtained from the armature. The physiological effects of this current differ somewhat from that obtained from the armature, but the extent and exact nature of these differences I have not yet determined

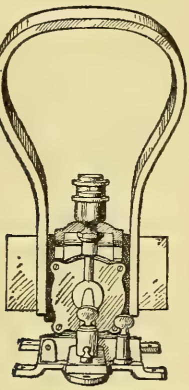

FIG. 4.—IMPROVED SINUSOIDAL APPARATUS DESIGNED BY THE AUTHOR, GIVING TWO DISTINCT CURRENTS.

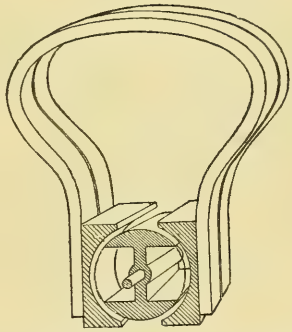

FIG. 5.—SECTIONAL VIEW OF THE SINUSOIDAL APPARATUS USED BY THE AUTHOR SINCE 1883.

as fully as I desire before attempting an accurate description. The speed of my new apparatus may be varied from a few alternations per second to more than seven thousand per minute. Fig. 2, Plate I, is a graphic representation of the curve obtained from the current furnished by the armature of this apparatus.

In a paper read before the American Electro-Therapeutic Association at its Chicago meeting, September, 1893, I called attention to some important differences in the effects obtained from my apparatus and that of d'Arsonval, which I think depend upon the differences in construction of the two machines. These differences will be apparent to any one familiar with d'Arsonval's description of the effects of the current of his apparatus.

In the use of the sinusoidal current from my apparatus different effects are observed, as in that of d'Arsonval, according as the machine is rotated slowly or at a high rate of speed. When rotated slowly and

connected with sponge electrodes, held one in each hand, vigorous contractions are produced in each arm, and in alternation, nearly all the muscles of the arm seeming to participate in the contractions. When one electrode is placed in contact with the feet and the other held between the two hands, the muscles of both extremities are made to contract vigorously. The contraction is spasmodic rather than tetanic in character. By proper adjustment of the current, strong muscular contractions may be induced without the slightest sensation in the skin, and without any pain sensation whatever. With one electrode placed in the rectum or the vagina, and the other upon the abdomen, strong contractions of the abdominal muscles may be produced, and even of the muscles of the upper thigh, without any sensation other than that of motion. I have frequently seen patients, while taking this current, shaking so vigorously under its influence that the office-table was made to tremble quite violently with the movement.

With rapid rotation of the machine, the current obtained is capable of producing strong tetanic contractions similar to those of the faradic machine. The only skin sensation produced by an application sufficiently strong to induce tetanic contractions is a slight prickling, very much less intense than that produced by a faradic current capable of exciting equally strong motor effects.

The sensory effects produced by the current are exceedingly interesting. As has been already stated, applications of the current sufficiently strong to produce vigorous muscular contraction are attended by no sensory effects whatever. The sensory effects are best obtained by giving the machine a high velocity. Adjusting the apparatus for high velocity, and applying the sponge electrodes, well moistened, to the temples, with a gradually increasing current and with the eyes closed, one seems to see rotating waves of light resembling a luminous whirlpool in the region of each electrode, but without other sensation except a metallic taste.

It is a curious fact that the position of this luminous field is not stationary; it moves with the electrode, which seems to be the centre of the illuminated area. As the current is increased in strength the display of light increases in brilliancy, finally becoming so extended and intense that the whole front portion of the head seems to be brightly illuminated. At this point one begins to experience very slight prickling sensations in the skin, and a peculiar pulling sensation, which increases as the intensity of the current is increased. A remarkable characteristic of the current is, that so strong impressions are made upon the optic nerves, or their centres, by a current too delicate to be recognized by the nerves of the skin. This effect must be due to the great penetrability of the current.

The therapeutic indications for which I have employed the sinusoidal current have been based upon the peculiar motor and sensory

effects which I first observed ten years ago, some of which have since been observed and described by d'Arsonval and Apostoli.

Within the last ten years I have made more than twenty thousand applications of the sinusoidal current. Twelve thousand of these applications have been made within the last three years. The greater number of the applications have been made in gynæcological cases, although hundreds of applications have been made in cases not belonging to this class.

Rapidly-Alternating Sinusoidal Induced Current.

I have during the last year (1893) been employing, with very interesting results, an induced current obtained by energizing the primary coil with a rapidly-alternating continuous or sinusoidal current, the rate of alternation being nearly 17,000 per minute, the machine running at the rate of 1400 revolutions per minute, 12 alternations being made with each revolution.

The induced current obtained by using this current to energize the primary coil appears to be possessed of very remarkable properties. When using a bobbin wound with two hundred feet of No. 36 wire with a resistance of 80 ohms, with an exciting current of 20 milliampères, not more than one-fourth of the primary coil can be at first covered by the bobbin, the current being as strong as can be borne. After a few seconds, however, the bobbin can be slipped along over the core, and before the end of one minute the entire strength of the coil can be tolerated. At the end of three minutes the sensation felt from the current is almost completely abolished, although the amount of the current still remains the same, as indicated by the milliampèremeter placed in the inducing circuit. In several cases in which the application was made to the hands, I tested the sensibility with an æsthesiometer before and after the application, and found the distance at which the two points could be distinguished to have increased in one instance from seventeen to nineteen and one-half millimetres, and in the other from seventeen to twenty-one millimetres.

In another experiment, in which the tactile sensibility of the sole of the foot about an inch and a half posterior to the toes was tested, two points were distinguished at a distance of ten millimetres before the application of the current, and after the current was applied the distance was increased to fourteen millimetres.

An experiment with the chronometer, for the purpose of determining the effect of the current upon the time required for perception, gave more remarkable results. Before the application of the current the time required for the average of ten experiments gave 0.141 second as the time required for the perception of tactile sensibility and withdrawal of the hand. After the application the average of ten experiments gave 0.223 second.

The tracing taken from this current shows it to be distinctly sinusoidal in character. (Plate III, Fig. 3, A.) This current may be made or broken at any time without the slightest shock to the patient, or any other change than a cessation of sensation produced by the current.

I am convinced, from the experiments which I have made, that this current is a powerful stimulant of the metabolic processes of the body. As one means of testing its effects, I submitted a young and vigorous man to a careful test of the strength of each of his groups of muscles, using for the purpose a dynamometer which I have constructed for such uses. After the test had been applied, the patient was submitted to electrization by means of the current described in the following manner: With the subject lying upon the table, an electrode was applied the whole length of the spine, another large and broad electrode covering the abdomen. A current was passed through the body for ten minutes; electrodes of suitable size were then applied in succession to the upper arms, the thighs, and the calves, five minutes in each location. The patient was then again subjected to the same test as before. It was found that the total lifting capacity of the patient increased in the interval from 4328 pounds to 4639 pounds,—a gain of 311 pounds. A notable gain was especially noted in the muscles of the arms. The second test was applied about thirty minutes after the first. Both tests were carefully made, care being taken to see that the patient used his muscles to their full capacity in each test. Repeated examinations of a similar sort have convinced me of the powerful influence of this current upon the tissues, as shown in the removal of the sense of muscular fatigue, which is doubtless effected through the absorption of oxygen.

Electric Currents of Great Frequency.

Prof. A. d'Arsonval, of Paris, communicates to the *Archives de Physiologie* for April, 1893, a note giving the result of further researches upon the effect of rapidly-alternating electric currents. D'Arsonval had previously shown that, with sinusoidal waves of great frequency, neither the nerves nor the muscles are excited,—consequently, neither pain nor muscular contraction is produced; but great tissue-activity is produced, as shown by the great absorption of oxygen and the increased production of CO_2. Changing the form of the waves, each wave produces an electric shock; and by increasing the number of waves not only is the number of shocks increased, but the contractions become more and more confused until the muscle remains contracted or tetanized. To produce this condition in human muscle requires from 20 to 30 excitations per second. When the muscle is tetanized, if the number of waves is increased, the intensity of the phenomenon of excitation is also proportionally increased, but this does not continue indefinitely, as might be supposed. A maximum is reached between 2500 and 5000 excitations per second, after which the phenomenon of excitation de-

creases with the number of electric oscillations. From this results the surprising fact that, with oscillations sufficiently rapid, currents may be passed through the body without being felt which would produce most terrific effects if the frequency of oscillations was lessened.

D'Arsonval first called attention to this remarkable fact in 1888; but at that time the apparatus which he employed did not produce alternations of sufficient frequency to suppress the phenomenon of excitation entirely, his machine giving scarcely more than 10,000 excitations per second. He has since, however, by combining this apparatus with that of Dr. Hertz, succeeded in producing alternations at the astonishing rate of one billion per second. D'Arsonval describes three different modes of producing alternating currents of great frequency, as follow: (1) the induction coil of Ruhmkorff; (2) an alternator made upon the principle indicated by M. Gramme; (3) the oscillating discharge of the condenser.

The induction coil and the alternator are both inferior to the condenser as means of securing oscillating discharges of great frequency. Both were discarded by d'Arsonval in his experiments in favor of the method employed by Dr. Hertz, which is based upon phenomena first discovered by Fedderson, and studied nearly half a century ago by Helmholtz and Sir Wm. Thomson. The latter discovered the following mathematical law relating to the discharge of the condenser. I translate as follows from the article by d'Arsonval above referred to:—

"If a Leyden jar is discharged by means of conductors, two very different cases may present themselves, according to the relative value of the capacity (C) of the co-efficient of self-induction (L) and of the resistance (R) of the system. If we find $R > \sqrt{\frac{4L}{C}}$, the discharge is continuous; in a contrary case, it is oscillatory. In the case of the oscillatory discharge the oscillations are isochronous, and their amplitude decreases in a geometrical ratio. The movements of a liquid in communicating jars will represent what occurs with the Leyden jar. According to the resistance offered to the movement of the liquid, the surface of the liquid finds a position of equilibrium slowly and without rising above the point of equilibrium, or there may be a series of oscillations with decreasing amplitude. The duration and number of oscillations may be measured by examining the discharge by means of a turning-mirror. When the resistance is so slight as to be negligible, the duration of an oscillation is given by the formula of Thomson: $T = 2\pi\sqrt{LC}$.

"We may, consequently, give to T values more definite by modifying L and C. Dr. Hertz has obtained one-billionth of a second; and my friend, M. Potier, has been able to lower the oscillating period so as to give to the Leyden jar a musical sound perceptible to the ear. In my first experiments I employed a Hertz vibrator; later, I employed the more powerful arrangement suggested by MM. Elihu-Thomson and

Tesla. In my recent researches I found great advantage in the exclusive employment of the following apparatus, of which the experiments of M. Lodge have given me many suggestions: Let *A A′* (Fig. 6) represent the armatures of two Leyden jars arranged in cascade. The armatures are joined to an electrical apparatus of high potential (as a Holtz machine, Ruhmkorff coil, or transformer). The external armatures, *B B′*, are joined together by a solenoid, *C C′*, composed of coarse copper wire, making fifteen or twenty turns. Each time a spark passes between *A A′* an oscillating current of extreme energy is produced in the solenoid, so that by connecting its extremities, *C C′*, a current is produced which may bring to a white light a strong incandescent lamp, *L*, held between two persons, *D D′*. The spark which is obtained between *C C′* is much longer than that which passes between *A A′*. This is due to the fact that in the latter case the discharge of the external armature, *B B′*, occurs suddenly, while that of the internal armature, *A A′*, is slowly developed, the difference in potential between the poles increasing until the spark passes. In these conditions the position of the solenoid plays a secondary rôle, while its self-induction becomes preponderant. The effect of these sudden discharges is analogous to those facts in mechanics relating to the action of instantaneous forces. A piece of gun-cotton placed upon a piece of steel burns slowly if lighted, but will break the piece if made to explode by means of fulminate of mercury. The same amount of energy, however, has been set free in the two cases; but in the second the pressure generated by the gas is so intense that the resistance of air becomes comparable to that of steel. This is the principle illustrated in the difference between the electrical pressure developed gradually in *A A′* and, on the contrary, suddenly in *C C′* at the moment when the jar is discharged. If it is desired to increase the tension of the current, it is sufficient to introduce into the solenoid a bobbin with a large number of turns. This bobbin is placed in a tube of glass filled with oil (Fig. 7), which insulates it completely.

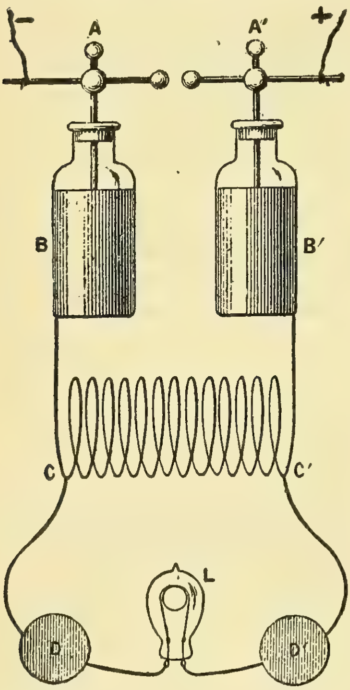

Fig. 6.—Arrangement of Leyden Jars for Producing Alternating Currents of Great Frequency. (D'Arsonval-Hertz.)

" We may utilize in two different ways the currents thus obtained:

First, by passing them directly through the tissues; second, by placing the tissues on the interior of the solenoid without making any communication with it. In the second case, the tissues placed in the solenoid are the seat of induction currents of extreme energy. They act like conductors closed upon themselves, and are traversed by induced currents of great intensity. From a physiological point of view, the effects obtained are the same in the two cases, and are chiefly as follow: First, no effect upon the general sensibility and muscular contractility. This is the most striking phenomenon. We have currents capable of burning to incandescence a series of electrical lamps. These lamps placed between two persons, *D D′* (Fig. 6), completing the circuit, are lighted without producing any sensorial impressions. The current is very strong. A little heat may be experienced at the points of entrance and exit of the current from the body. I have been able to pass through my body currents of more than 3000 milliampères, when currents of a quantity ten times less would be extremely dangerous if the frequency in the place of being 500,000 to 1,000,000 per second were lowered to 100 per second, the

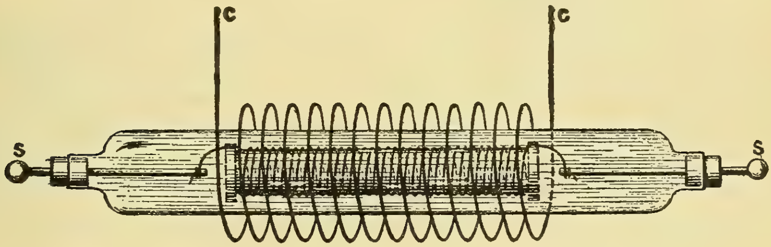

FIG. 7.—SOLENOID AND COIL FOR USE IN CONNECTION WITH CONDENSERS.

usual rate of alternating currents employed for medical purposes. There has been much anxiety for an explanation of these paradoxical results to which I first called attention in my lectures at the College of France and at the Society of Biology. In my communication to the Society of Biology I suggested two hypotheses: 1. Whether these currents, on account of their enormous frequency, pass exclusively upon the surface of the body (it is well known that ordinary currents of great frequency do not penetrate, but flow upon the surface of the conductor, as does static electricity). 2. Whether the sensory and motor nerves are organized to respond only to vibrations of determined frequency, as we see, for example, in the case of the optic nerve, the terminations of which are blind to the undulations of ether at a rate less than 497 billion (red), and greater than 728 billion per second (violet).

"The acoustic nerve is in the same situation as regards sonorous vibrations. Below and above certain vibratory periods, musical sounds no longer exist, and the ear remains insensible to these vibrations. The human body does not behave like a metallic conductor. Currents of

great frequency, in the place of flowing on the surface of the body, penetrate into the body and influence nerve-centres deeply situated, both directly and by producing induced currents. Whether these currents are direct or induced, the sum-total of the energy which traverses the body remains the same, and the result is the same in both cases. By employing a current of great frequency, the body is traversed without showing any reaction by currents, the energy of which would destroy it if the frequency were lowered. We can explain this innocuousness by the absence of excitations, or, better still, by supposing that these currents exercise upon nerve-centres and muscles the remarkable special action studied by Brown-Séquard under the name of inhibition. Experiments, in fact, demonstrate in the most striking manner this inhibitory action of currents of great frequency, as we shall now show:—

"1. The tissues traversed by these currents become rapidly less excitable to ordinary excitants. This diminution shows itself by a remarkable analgesic effect produced at the point where the current penetrates the body. This analgesia persists, according to the case and subject, from one to twenty minutes.

"2. The vasomotor system is powerfully affected. If, for example, the mercurial manometer is placed in the parotid of a dog, the arterial pressure is observed to fall several centimetres under the influence of this form of electrization. We may observe the same phenomena in man by the aid of a sphygmograph. There is then manifest inhibition of the vasomotor system, aside from all conscious sensation. This fact proves that currents of great frequency penetrate deeply into the body, as I have stated above.

"3. Continue the currents a sufficiently long time in man, and the skin becomes reddened and is covered with perspiration,—a natural consequence of the action of the current upon the vasomotor centres. The same result is obtained by placing the subject upon an insulated stool in communication with one of the poles of the high potential, the second pole being in communication with a metallic plate, supported at a sufficient distance from it. The patient is thus submitted to the action of an oscillating electrical field.

"4. By submitting an entire animal to these currents, either directly or by placing it in the solenoid, we may observe an increase in the intensity of the respiratory combustion. The thermometer shows that there is no increase in the internal temperature. The excess of heat produced is lost by radiation and evaporation, as may be observed by placing the animal in one of the calorimeters which I have briefly described.

"5. To discern the action of these currents in a living cell I have employed the yeast of beer, and in collaboration with M. Charrin I have studied the bacillus pyocyanic.

"The results which I have briefly indicated, and those already obtained in clinical experiments, give me the hope that we possess, in these various forms of electricity, important therapeutic resources."

The sensation produced by the Tesla apparatus seems to resemble very closely the effects of the current obtained from a powerful Holtz machine, and I have no doubt the current by which the brilliant experiments of Tesla are produced is practically identical with that obtained by d'Arsonval and Hertz from a static apparatus, although obtained in so different a manner These experiments certainly demonstrate very clearly that all the different forms of electricity are simply phases of one great force. The therapeutic use of alternations of great frequency is a subject which remains to be elucidated in the future. I have recently obtained an apparatus for producing the currents of enormous frequency as described by d'Arsonval, and shall acquaint myself with the therapeutic value of this current, which is at present an unknown quantity.

THE TREATMENT OF DISEASES OF THE UTERINE APPENDAGES BY ELECTRICITY.

By AUGUSTIN H. GOELET, M.D.,
NEW YORK.

Diseases of the Uterine Appendages.

Anatomy.—The Fallopian tubes are prolongations from the uterine cornua on each side of the uterus, and the several coats are directly continuous with those of the uterus. They occupy a position along the upper (free) border of and within the folds of the broad ligaments, and vary in length from three to four inches. The right is frequently longer than the left.

The tubes are divided into three parts, viz., the isthmus,—the narrow, straight portion near the uterus, about an inch in length; the ampulla,—the curved portion, which is longer than the other; and the infundibulum or pavilion, called also the fimbriated extremity on account of its peculiar arrangement. The direction of each tube is outward and slightly upward for the first inch; then it curves forward and finally backward and inward toward the ovary, which occupies a position below and somewhat behind the ampulla, or curved portion, and between the extremity of the tube and the uterus.

The calibre of that portion of the tube known as the isthmus is very small, admitting only a fine bristle. The diameter of the whole thickness on transverse section is about two or three millimetres. The calibre of the ampulla is larger, admitting an ordinary uterine sound, the whole tube at this portion having an average diameter of about six to eight millimetres. The extremity or infundibulum is expanded, funnel-shaped, and separated into fimbriæ, one of which, longer than the others, is attached to the ovary. The others float freely in the peritoneal cavity.

The tube is composed of three layers like the uterus, viz., a peritoneal or outer coat, a middle or muscular layer, and mucous membrane which lines the tube. (I venture to suggest the term "endosalpingium" to designate this mucous lining of the tube.) A loose connective tissue of elastic fibres intervenes between the peritoneal covering and the muscular layer. The muscular structure of the tube is composed of unstriped muscular fibre, and is arranged in two layers, the outer running longitudinally and the inner circularly. The mucous membrane lining the tube, or the endosalpingium, as it might appropriately be called, is arranged in longitudinal folds, which are more conspicuous in the ampulla, and is covered with columnar ciliated epithelium, the motion of the cilia being in the direction of the uterus. There is no submucous layer, and most

authorities contend that there is no glandular structure, but Bowman and Hennig claim to have discovered a peculiar tubal gland.

Upon this point Bland Sutton says, "The structure of the mucous membrane of this tube has been so carefully and systematically examined by competent experts that mere facts are beyond dispute, but they will admit of a different interpretation to that usually placed upon them, and arguments will now be advanced in order to show that the folds in the tubal mucous membrane are glands." He then proceeds to show that the tubal mucous membrane of other mammals contains glands, and it is thrown into longitudinal folds similar to those of the human Fallopian tubes. He gives an illustration from Schenck showing that these ridges and folds are disposed in the tubes on the same principle as the glands in the uterus, and remarks that the most instructive age at which to observe the Fallopian glands is in the tubes of the fœtus at birth, at which time they attain their greatest complexity. The probable function of the Fallopian glands, he thinks, is to provide an albuminous fluid for the ovum as it traverses the tube.

At the uterine end of the tube the mucous membrane is continuous with that of the uterus, which will explain the frequent extension to the tube of an inflammation involving the endometrium. At the fimbriated extremity the mucous membrane sometimes projects beyond the tube, and bulges over the peritoneal covering. Occasionally, however, the peritoneum extends a distance along the fimbriæ. The abdominal ostium opens into the peritoneal cavity.

The arterial supply of the Fallopian tubes is from the ovarian arteries. The veins from the tubes enter the pampiniform plexus on each side. The lymphatics join with those from the upper part of the uterus and from the ovary and terminate in the lumbar glands.

The nerves are derived from the inferior hypogastric or pelvic plexuses, situated at the side of the rectum, vagina, and bladder, which, in turn, are derived from the hypogastric plexus of the sympathetic, situated in front of the promontory of the sacrum.

The ovaries are two flattened, oval-shaped bodies, situated one on each side of the uterus, below the outer extremities of the tubes, attached to the anterior and projecting through the posterior layers of the broad ligaments. The average size of the normal ovary is one and one-half inches in length, three-fourths inch in breadth, one-half inch in thickness, and it weighs about eighty-seven grains. The superior surface of the ovary is nearly flat, and the inferior is convex. The posterior border is flattened and free; the anterior is flattened and attached to the broad ligament. This point of attachment, which affords an entrance for the vessels and nerves supplying the ovary, is called the hilum.

Each ovary is connected with the upper angle of the uterus by a band of organic, muscular fibres, about an inch in length, continuous with the muscular fibres of the posterior wall of the uterus, called the

utero-ovarian ligament. The muscular structure of the organ is derived from this source.

The ovaries are supplied by the ovarian arteries, which come directly from the aorta. The veins join with those from the tubes and upper part of the uterus, forming the pampiniform plexus, which is a nest of veins situated in the folds of the broad ligament beneath the tube. The vein leading from this plexus on the right side empties into the inferior vena cava; that on the left side empties into the left renal vein. These are called the ovarian veins. The lymphatics unite with those from the tubes and upper part of the uterus and terminate in the lumbar glands. The ovaries derive their nerves from the same source as the tubes.

The ovary is not covered entirely by peritoneum, but that portion which projects through the posterior layer of the broad ligament is covered by a layer of short columnar epithelium, from which the primitive ova are supposed to spring. This epithelium differs only from that lining the Fallopian tubes, with which it is sometimes continuous through the attached fimbria uniting the tube and ovary, in being destitute of ciliæ. Beneath this outer layer is a thin, dense, musculo-fibrous structure, called the tunica albuginea. This layer is intimately blended with the stroma of the ovary beneath it.

In this connection it may be as well to mention the remains of the Wolffian body, called the parovarium, or organ of Rosenmüller, which consists of a series of narrow tubules situated in the folds of the broad ligament on each side, between the ampulla of the tube and the hilum of the ovary, from which cysts frequently develop.

SALPINGITIS.

Although recent writers have considered salpingitis and ovaritis together, under the head of salpingo-oöphoritis, or oöphoro-salpingitis, because they are so frequently associated, and under the impression that it is impossible to separate them clinically, I shall adopt a separate classification, both for the sake of convenience and because I believe they may exist as distinct affections, and that ovaritis may occur independently of infection or any preceding lesion of the tubes.

Etiology.—The statement that salpingitis is most frequently due to the extension of an inflammation from the endometrium to the tube is probably, in the main, correct, especially when it is septic; but that salpingitis may occur coincidently with a similar condition of the endometrium, from the same causes that produce the other condition, I firmly believe. For instance, a catarrhal endometritis or a hyperæmia of the endometrium may be brought about by exposure to cold during menstruation sufficient to produce suppression, too frequent and excessive coition, erotic excitement, or some of the methods employed for the prevention of conception, such as withdrawal, the cold-water douche, etc., which operate by producing a general pelvic congestion.

It is fair to suppose, therefore, that a hyperæmia of the mucous lining of the tubes will likewise occur, and that it may be produced coincidently with a similar condition in the cavity of the uterus. In support of this point, the fact may be recalled that a catarrhal salpingitis is frequently found in virgins, where septic infection is out of the question.

Undoubtedly, however, the chief cause of inflammation of the appendages, especially when of a septic character, is inflammation of the endometrium, and that it results from direct extension, owing to the continuity of the mucous membrane of the tubes with that of the uterine cavity. The majority of writers believe this is the only method of infection, but Championnière believes that the lymphatics carry infection in other than puerperal conditions. Pozzi opposes this view, but thinks the part played by the lymphatics should not be ignored. He calls attention to the fact that adhesions often bind the fundus of the uterus to the appendages, and that these adhesions are almost entirely composed of lymphatics which connect the subendothelial uterine plexus with the lymphatics of the appendages. He regards these adhesions as the result of the action of a previously existing endometritis upon the deep lymphatic plexus, of which the subendothelial plexus is merely a continuation, and thinks it possible that septic inflammation may be conveyed from the uterus to the tubes and ovaries through this channel.

Whatever the method of infection, the causes of septic salpingitis may be regarded as the same as that of septic endometritis, which may be enumerated as gonorrhœal infection, puerperal infection following labor or abortion when septic conditions occur, direct contamination from the introduction of instruments or tents into the uterus for exploration, and surgical operations upon the uterus.

Attention has been directed by some writers to the influence of the eruptive fevers, especially scarlatina and variola, in producing salpingitis.

Varieties.—The term "salpingitis" has been used so indiscriminately that its correct interpretation is frequently quite impossible. The confused classification of all the varieties of tubal inflammation under the head of salpingitis or salpingo-oöphoritis is very unsatisfactory and productive of much confusion, as it may mean many things combined.

The division of salpingitis into catarrhal, interstitial, and suppurative, as adopted in a recent work by the writer,[1] is in accord with modern views, and is, in the main, satisfactory, but may be improved upon by using the term "endosalpingitis," as employed by A. Martin, to denote an inflammation of the mucous lining of the tube, and salpingitis to indicate inflammation of the muscular structure of the tube-wall. Perisalpingitis, it is understood, signifies inflammation of the peritoneal covering. It appears reasonable to apply the same classification to

[1] The Electro-therapeutics of Gynæcology.

denote inflammations of the tubes as that employed for similar affections of the uterus, and it would certainly be less confusing. Objection may be raised on account of the impossibility of always separating, clinically, an endosalpingitis from inflammation of the muscular structure of the tube, since they are so often associated; but the same objection applies to inflammations of the uterus. Still, the classification holds there.

Endosalpingitis may exist as a simple catarrhal inflammation, when it may be either acute, subacute, or chronic, with or without involvement of the muscular structure; or, like the endometrium, the mucous membrane of the tube may be attacked by suppurative inflammation as the result of septic infection, though it does not long remain confined to the mucous membrane, the parenchymatous structure being rapidly involved.

Interstitial or chronic parenchymatous salpingitis may sometimes result from a long-standing catarrhal endosalpingitis, but, according to some authorities,[1] it exists as a distinct affection, with a marked tendency to acute exacerbations, which renders its differentiation from acute catarrhal salpingitis sometimes difficult.

ENDOSALPINGITIS.

Pathology.—Acute catarrhal endosalpingitis is a mild type of inflammation resembling a catarrhal endometritis. The mucous membrane is hyperæmic and swollen, and the mucous secretion is greatly increased. The whole tube is enlarged from tumefaction and infiltration. Sometimes the abdominal ostium is patulous and the fimbriæ remain unaltered in shape, though turgescent, but they are sometimes folded in like an unopened flower. The tumefaction of the mucous membrane sometimes leads to temporary obstruction of the lumen of the tube and retention of the secretions, causing at times considerable discomfort. The muscular structure is not apt to be much or seriously affected, though infiltration into the muscular layer sometimes occurs and the walls are much thickened. This, however, subsides with the inflammation.

In the chronic stage the active hyperæmia gives way to a more passive condition, the tumefaction subsides, and the secretion is diminished. The lumen of the tube, though not normal, is usually sufficiently patulous to allow drainage into the uterus. Under favorable conditions and appropriate treatment, a complete cure can frequently be brought about in these cases.

Bland Sutton has drawn attention to the association of catarrhal salpingitis with adenoma of the cervix, and he believes that frequently the one is secondary to the other.

Diagnosis.—Acute endosalpingitis gives rise to symptoms very similar to those of a localized pelvic peritonitis. There is sharp pain in the

[1] Pozzi, for instance.

region of the tubes (usually both sides are affected), with tenderness to pressure upon the abdomen in the same locality, and associated with it there is often a moderate rise of temperature. The pain radiates upward toward the epigastrium and down the thighs. Digital examination reveals great tenderness, but it is seldom possible in this stage to map out the swollen tubes. There is usually an accompanying endometritis, and the character of the discharge from the uterus will ordinarily be sufficient to determine the nature of the tubal inflammation, by eliminating a suppurative condition. Finally, investigation of the cause which may have given rise to the attack will aid materially in establishing the diagnosis.

When the acute attack has subsided and the condition has become subacute or chronic, a diagnosis is usually less difficult. There are dragging sensations, with dull aching in one or both ovarian regions, and occasional sharp attacks of pain. These symptoms are very much aggravated by the erect position, walking, or exertion of any kind. Sometimes the patient is unable to stand erect, and walks bent forward. The vaginal discharge, which is more or less profuse, resembles the white of an egg.

Pozzi regards the association of endometritis with endosalpingitis so inseparable as to almost warrant a diagnosis of the latter when the former condition is present. It may often be too trivial to give rise to serious symptoms, but quite sufficient to account for the tenderness in the tubal regions.

Dysmenorrhœa is constant and peculiar in that it is apt to precede or follow menstruation. Menstruation is often followed by marked prostration, lasting from several days to a week. Constipation is frequent, and defecation is often painful. The ovarian regions are sensitive to pressure from without, and digital pressure in the vagina elicits marked tenderness, especially on the left side, which is most apt to be affected on account of the greater blood-supply on that side, and on account of the proximity of the left tube to the upper part of the rectum.

There is no permanent fixation of the pelvic contents in catarrhal endosalpingitis, but sometimes extreme tumefaction of the surrounding tissues may give rise to some evidence of incomplete mobility, which disappears with its subsidence. This tumefaction may interfere with satisfactory palpation of the tubes, but they can sometimes be distinctly outlined.

Catarrhal endosalpingitis is apt to be recurrent, and is often confounded with oöphoritis, or some more serious form of salpingitis.[1] Doubtless many of these cases have been mistaken for a more serious condition and submitted to operation. In the chronic stage the uterine end of the tube may become obstructed from tumefaction of the mucous membrane, and the tube distended from retained secretions, giving rise

[1] Bland Sutton.

to localized, tender swellings in the pelvis. But these disappear on the subsidence of the tumefaction, which allows the secretions to be emptied into the uterus. No doubt many of these cases of distended tubes have been diagnosed as hydrosalpinx and removed as such, but they are not to be regarded as typical cases of hydrosalpinx, which is of longer standing and never occurs in acute conditions.[1]

Treatment.—In the acute stage bipolar faradization of the vagina will afford much relief, if it is well borne and properly applied, by lessening the tumefaction and congestion and the pain consequent upon this condition. Strict observance of several conditions is, however, absolutely necessary, to prevent its application doing actual harm; and unless it is well borne at the start, or if it fail to afford prompt relief, it should be abandoned. A thorough appreciation of the qualities of the secondary faradic current, as derived from differently-constructed coils, is absolutely prerequisite to anything like success in employing this current, and will often enable a careful operator to succeed where another would fail. A description of the apparatus necessary to obtain a suitable current for these acute conditions would be out of place here, and the reader is referred to a recent work[2] by the writer for such information, as well as for a detailed account of its application.

Fig. 1 represents a faradic battery made according to a design suggested by the writer, which gives ten currents of as many different qualities, making it suitable for all kinds of gynæcological work. The coils, four in number, are placed inside the box, under the key-board face. It is arranged to be operated by the chloride-of-silver cells for outside work, when a portable battery is desired, and there are connections for stationary cells. For office work it is operated by four or six Leclanché cells. The current is turned on by means of a permanent rheostat in secondary circuit.

The essential features of the secondary current for producing sedation are (1) extremely high tension, (2) rapid and perfectly smooth interruptions, and (3) very gradual attainment of the maximum intensity.

To attain the requisite degree of tension it is necessary that the coil (the secondary) from which the current is derived should be composed of the finest wire, of the greatest possible length. The reason for this is evident, for the volume of the current is diminished in proportion to the length and fineness of the wire, on account of the increased resistance, and it is this quality in the faradic current which causes painful contractions; also the electro-motive force of the current is increased by multiplying the number of convolutions exposed to the inducive influence of the primary coil, and the fineness of the wire allows more convolutions on a given coil.

The necessity for smooth vibrations is obvious. By multiplying the

[1] Bland Sutton. [2] The Electro-therapeutics of Gynæcology.

rapidity of the interruptions the ability of the muscles to respond to every impulse is diminished, and relaxation is more rapidly established. It is this state of relaxation (which should be absolute) that is essential for perfect sedation.

The gradual attainment of the maximum intensity of the current administered, though mentioned last, is by no means a less important consideration in bringing about the desired effect. To accomplish this satisfactorily it will be necessary to employ a well-regulated rheostat or current-controller either in the battery circuit or in the secondary circuit, and the strength of the current should be increased so gradually that it is barely perceptible to the patient throughout the entire *séance*.

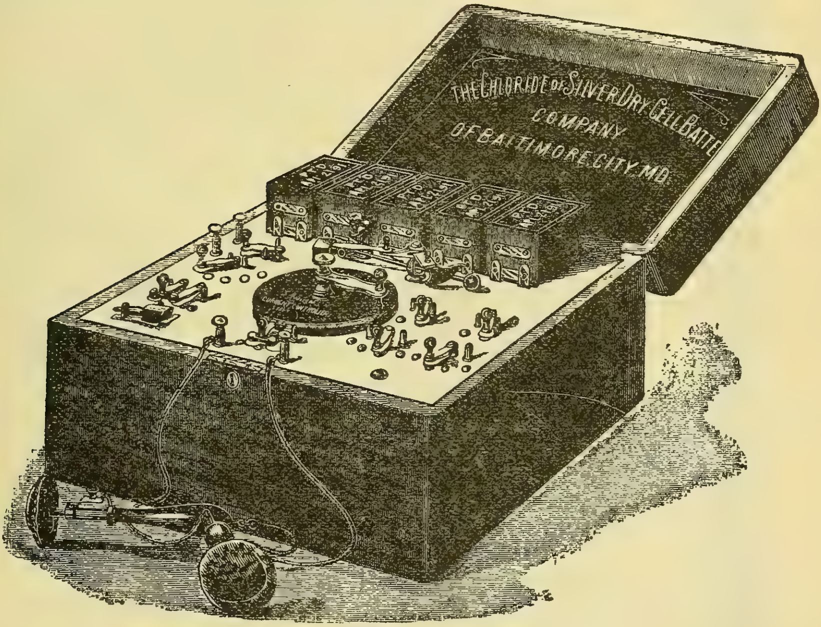

FIG. 1.—GOELET'S IMPROVED FARADIC BATTERY.

It should never produce the least unpleasant sensation, and the maximum intensity employed should be limited by the effect produced; that is, it may be increased until a point is reached when the patient declares herself relieved. Ordinarily this will consume from twenty to thirty minutes. At the same time care must be observed not to fatigue her, and she must be allowed to assume throughout a perfectly comfortable position in bed.

A delightful sense of relief and repose, which continues for a variable length of time, will be induced by this application in appropriate conditions, and it should be repeated as required for maintaining absolute freedom from pain.

Employed in this manner electricity can be made to take the place

of opium and other sedative remedies usually employed in this stage of salpingitis, and it will be found much more satisfactory; or it may be made to supplement the ordinary method of treatment. It is needless to say that absolute rest in bed should be enjoined in this stage.

Goelet's Improved Apostoli Bipolar Vaginal Electrode.—The modification consists in shortening the shaft of the instrument, which is unnecessarily long in the original, and constricting it just external to the outer metallic surface, so as to allow the ostium vaginæ to grasp and hold it in position without the support of the hand. The shortening and narrowing of the shank likewise render that portion lighter and makes it more easily retained.

Fig. 2.—Goelet's Improved Apostoli Bipolar Vaginal Electrode.

The electrode should be warmed by immersion in warm water to which has been added an antiseptic (lysol or creolin are preferred), and vaselin should be used to facilitate its introduction. Care must be taken to have both metallic surfaces of the electrode wholly within the vagina, and it should be supported gently, without exerting too much pressure upon sensitive points within the pelvis, to prevent its being forced out of position by the contractions of the vagina. In making the connections with the battery, attach the cord from the positive pole to the attachment on the electrode leading to its extremity, so that the positive pole will be applied to the sensitive vaginal vault. The necessity for observing rigidly the above technique cannot be too strongly emphasized. The use of galvanism is positively contra-indicated in this stage.

In the subacute stage vaginal bipolar faradization (current of tension) should constitute the principal treatment, but an occasional galvanic application with the positive pole in the vagina and a moderate strength of current will be permissible, and may be advantageous. The faradic current should be applied with the same care as recommended in the acute stage. Sedation and relief of pain are still the chief indications for treatment, and the current from the same coil must be employed at first, and a more stimulating current from a shorter coil may be substituted as soon as the former ceases to be beneficial. Experience here is essential in making a proper selection of the current that will afford the most benefit. Usually in this stage the patient can be treated at the office, and once in twenty-four hours is sufficiently often to repeat the application.

The galvanic current may be applied in a strength of 20 to 30 milliampères for ten minutes every second or third day, and it will be best to follow it each time with an application of the faradic current, as described, for a period of ten minutes. The carbon ball clay-covered electrode should always be used with the positive pole of the galvanic current in the vagina, and in these cases the external electrode should be placed over the lumbar region to obtain the best result.

FIG. 3.—GOELET'S CARBON - BALL CLAY-COVERED ELECTRODE.

Applications of both the galvanic and faradic currents (the latter by the bipolar method) have been advised in this stage to the interior of the uterus by Apostoli, but I do not regard it necessary, and believe that, in many instances, an undesirable degree of irritation will be provoked. When it is possible, interference with the cavity of the uterus should be carefully avoided in acute and subacute inflammatory conditions of the appendages. The cervix is generally patulous in this stage, and drainage from the uterus is sufficient; therefore a negative application to the canal is not required. And it must be remembered that the endometrium is extremely sensitive, and resents the slightest intrusion; therefore the introduction of electrodes for the application of the positive pole of the galvanic current, or for bipolar faradization of the uterus, in the belief that the action should be beneficial, is likely to provoke an irritation that will more than counterbalance any good to be derived from such applications. I have found the vaginal applications sufficient, for which reason, if for no other, I must consider the intra-uterine applications unnecessary.

In the chronic stage the first object of treatment should be to relieve the sensitive condition of the vaginal vault and the pain, which is more or less a constant accompaniment, and to hasten subsidence of the tumefaction, which interferes with drainage of the tubal secretions into the uterus. The relief of pain is best accomplished by daily applications of bipolar faradization to the vagina with the current of tension for fifteen, twenty, or thirty minutes, as required for producing absolute freedom from pain. The relief afforded will continue for a variable length of time, and the local effect, which may be compared to that of morphine, may be prolonged by enjoining rest from all exertion in the recumbent position for several hours following the application. I have known the application to give absolute relief for eight hours, even when the patient disobeyed the injunction to remain quiet. Then again, permanent relief has been

afforded by one application, and there has been no recurrence of the pain when she returned for treatment, twenty-four hours later. The effect of these applications, when properly administered, and the correct current employed are little else than marvelous, and must be seen to be appreciated. The skeptic cannot be blamed for discrediting what appears to be beyond human power. But it is a fact readily demonstrated. After the sedative effect of the application has worn off and the pain returns it is never quite so severe as before, and the analgesic effect of the current is more rapidly produced by subsequent applications. It is necessary, however, to call attention to the irritation produced by a loaded rectum, especially when the left side is the seat of the disease, and a loose condition of the bowels should be maintained. The irritation induced by retained fæces in the rectum will often interfere with the expected benefit of these faradic applications, and if temporary relief is obtained with the rectum still in this distended condition it will not be lasting. It is better, therefore, in all cases, to empty the rectum thoroughly before making the application. This digression is excusable, because these points are important.

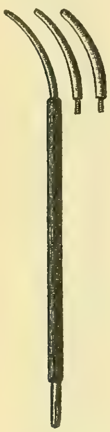

FIG. 4. — GOELET'S INTRA-UTERINE NEGATIVE DILATING ELECTRODE. (Five sizes.)

If the faradic current does not afford marked and permanent relief it may be supplemented by an occasional application of the positive pole of the galvanic current against the painful point in the vagina, placing the external electrode in a position to include the sensitive tissues directly between them. This current may be used every second day with a strength of from 20 to 30 milliampères for five or ten minutes, and the faradic can be used immediately after and on the intermediate day. Later, the strength of the current may be increased to 50 milliampères with advantage. The beneficial effect of electricity employed in this manner is obtained by diminishing the tumefaction and allowing drainage of retained tubal secretion into the uterus. The positive pole is preferred on account of its well-known depleting effect, which is produced by driving the fluid constituents of the tissues in the direction of the negative. It exerts, likewise, an analgesic effect, and is greatly aided by the subsequent employment of the tension faradic current. If the uterine canal is not pervious, so as to allow drainage from its cavity, it should be rendered so by passing, once in three or four days, the dilating cervical electrode with a current-strength of 10 milliampères, the negative pole being employed. This application, together with the positive pole to the vaginal vault and bipolar faradization of the vagina, can all be made at the same sitting, without causing the least inconvenience to the patient.

Galvanism of the tube is said to excite peristaltic movements, which favor drainage.

If any one doubt the power of the galvanic current applied through the vagina to remove tumefaction of the tubal mucous membrane, let him try the effect of overcoming nasal obstruction due to tumefaction or inflammatory hypertrophy of the mucous membrane by applying one pole on each side of the nose with a current of 5 milliampères. When the condition is one of inflammatory hypertrophy with induration, the action of the negative pole will be indicated, and it should then be employed in the vagina as the active pole.

The co-existing endometritis will ordinarily be overcome by maintaining drainage of the secretions from the cavity of the uterus by applications of the negative pole to the canal. The beneficial action of the current applied in this manner, even with the moderate strength necessary to effect dilatation, is no doubt due in a measure to an alterative effect upon the endometrium, with which the electrode comes in contact, if it is employed in the manner recommended by the writer, with an electrode two and one-fourth inches long, conical, and of a size sufficient to distend the canal. But if this should prove ineffective an increased strength of current may be used, and, where indicated by a profuse mucous discharge which is persistent, the positive pole may be employed with the platinum sound electrode to the whole length of the uterine canal. From 30 to 50 milliampères employed for five minutes every two or three days will be an effective strength for these applications of the positive pole to the endometrium in chronic catarrhal conditions. But it will be best to begin with only 15 milliampères and gradually increase the strength at subsequent sittings if necessary.

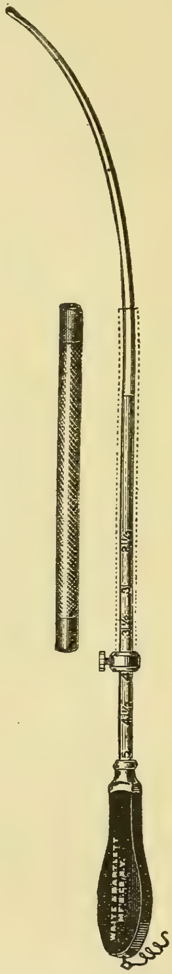

FIG. 5.—GOELET'S PLATINUM SOUND ELECTRODE, WITH FLEXIBLE SHEATH ARRANGED FOR MEASURING THE LENGTH OF THE UTERINE CANAL.

The pain is due, in some instances, to distension of the tube by retained secretions, and it cannot be permanently relieved by the faradic current alone; but there need be no apprehension of producing rupture if the tension current is employed by the bipolar method in the vagina. It will be necessary to empty the tube in these cases before permanent

relief can be obtained, and for this purpose the galvanic current is to be employed, by directing it through the side affected from the vagina to the abdomen. The obstruction in these cases is seldom permanent, though there is often considerable distension, producing a tumor which is often mistaken for hydrosalpinx and removed as such. According to a recent writer[1] who has given much attention to the pathology of these conditions, such cases of distended tubes are not to be regarded as true types of hydrosalpinx, unless destructive changes have occurred in the tubal structure, resulting in occlusion of both abdominal ostium and the uterine end of the tube. He believes that true hydrosalpinx is of longer standing, and is, most frequently, an advanced stage of pyosalpinx.

If a catarrhal endosalpingitis exist for a long time, it is possible, of course, that the parenchymatous structure of the tube may become involved and more active treatment will be demanded, but this will be described under its proper head.

The majority of these cases of catarrhal endosalpingitis are perfectly amenable to the method of treatment outlined above, and, though the treatment is sometimes tedious, a permanent cure can be obtained if the patient and attendant are sufficiently persistent in following it out. In some recent cases a rapid cure can be effected. Treatment of the co-existing endometritis is important.

INTERSTITIAL OR PARENCHYMATOUS SALPINGITIS.

Pathology.—Interstitial salpingitis may result if a catarrhal endosalpingitis persist for a long time or exist in an aggravated form, but it is most frequently due to an aggravated type of inflammation in the tube, resulting from extension of a similar condition from the uterus, and may or may not be septic. It may be regarded as inflammatory hypertrophy of the muscular structures of the tube, or there may be a condition of hyperplasia of the muscular layer and connective tissue. The tube is enlarged in some instances to the size of the little finger, the enlargement being due to thickening of the tube-walls, and it often feels hard and cord-like. The tube is lengthened and distorted (thrown into coils), and is sometimes bound to the ovary and confined in Douglas's pouch by adhesions resulting from a perisalpingitis. It has been called pachysalpingitis by Kaltenbach. According to Pozzi, the abdominal ostium is always obliterated and the infundibulum adheres rather loosely to the ovary, but the uterine orifice of the tube is, on the contrary, usually permeable, which explains the absence of cystic distension.

It may exist in an acute or chronic state, but the acute process, as most frequently observed, is probably only an acute exacerbation in a tube previously in a state of chronic inflammation. There is a marked tendency to acute exacerbations, and in this shape it is often difficult to differentiate from an acute catarrhal endosalpingitis.

[1] Bland Sutton.

Pozzi believes that this form of inflammatory hypertrophy of the tube-walls sometimes occurs as the result of a cured purulent endosalpingitis where a pyosalpinx is not formed; that when the pus disappears, as may occur from prolonged drainage, a chronic endosalpingitis and parenchymatous salpingitis is established. He firmly believes that such cures are possible, and that chronic inflammation of the mucous membrane of the tubes, though less amenable to treatment than that of the uterus, may be completely cured to the extent of a *restitutio ad integrum.* Upon this point he says: "It is well known that such a result may occur in other localities; it is, therefore, reasonable to believe that it may occur here, especially if careful treatment be given to the uterine mucous membrane (anatomically and physiologically so closely connected with that of the tubes), placing a barrier about the tubal inflammation, and constantly re-inforcing the anatomical tissue-elements in their struggle against the microbes."

Diagnosis.—Chronic interstitial salpingitis may give rise to the same symptoms as catarrhal endosalpingitis, but they are usually more intense, and acute exacerbations are apt to occur more frequently. The two conditions are often confounded; but a careful distinction is important, since the one is much more serious and obstinate than the other. In the stage of acute exacerbation this is frequently impossible, but the history of the case may furnish some aid to a differential diagnosis. In some instances it will be necessary to wait for the subsidence of the acute process before a satisfactory conclusion can be reached.

When the acute symptoms have subsided, however, or in the chronic stage, there should be no difficulty in mapping out by conjoined manipulation the thickened, indurated, cord-like tubes, often tortuous and immobilized by adhesions, which give to the touch a sensation very different from the moderately-enlarged, softened tubes of a catarrhal endosalpingitis. Should any doubt exist in this stage, examination under an anæsthetic will materially aid in establishing a diagnosis. Menorrhagia and premenstrual dysmenorrhœa are important symptoms upon which to base a diagnosis, as they are apt to be more pronounced in this form of salpingitis than in the catarrhal variety, especiallv if the latter is of recent date.

That form of interstitial salpingitis which results from a cured pyosalpinx is to be distinguished from recent and less-important lesions by the fact that it usually involves both tubes, whereas the other may be unilateral.

Treatment.—In the stage of acute exacerbation the treatment will be the same as that outlined for acute catarrhal endosalpingitis, the chief objects being to allay the acute inflammatory process, to lessen its duration if possible, and diminish the congestion and pain of the chronic stage, which is often severe when the patient begins to get about on her feet.

When pain is a prominent symptom of the chronic condition, vaginal bipolar faradization, with the current of tension employed after the manner described in the treatment of chronic endosalpingitis, may be relied upon to give prompt relief. The applications should be made every day, and their duration should be sufficient to render the patient perfectly comfortable. When, in any case, this is not possible by faradization alone, vagino-abdominal galvanism, with the positive pole in the vagina and against the side where the disease is more pronounced, should be supplemented. This application may be repeated every day, with a moderate strength of current (from 20 to 30 milliampères), the carbon ball being well protected by a covering of clay or absorbent cotton. The duration of the application may be five or ten minutes, and it is to be followed every time by bipolar faradization for fifteen or twenty minutes. This undoubtedly affords the most satisfactory relief of the dragging sensations and colicky pains of salpingitis. Sarwinoff has demonstrated conclusively that these pains are due to a perineuritis and compression of the nerve-filaments; which is probably an explanation of the increased benefit usually obtained by an association of the galvanic with the faradic current.

As the case progresses and improvement becomes manifest the applications may be made every second day, and the strength of the galvanic current may, with advantage, be increased to 50 milliampères. When the sensitiveness to pressure has been, in a measure, overcome, the negative pole, with a current-strength of 20 to 40 milliampères, must be substituted for the positive in the vagina, to promote resolution of the hyperplastic inflammation of the tube-walls, to stimulate absorption of surrounding deposits, and loosen adhesions. Bipolar faradization may be continued with advantage, and aids in accomplishing these results by stimulation of the capillary circulation. To obtain the best result it sometimes becomes necessary to make the faradic current more stimulating by using a coil of shorter and coarser wire, but care must be taken not to overstimulate (or irritate), bearing in mind the fact that acute exacerbations are apt to occur, and are sometimes easily provoked. For this reason it is best, when possible, to avoid any interference with the cavity of the uterus, leaving the co-existing endometritis to a later period. When necessary, however, to facilitate drainage, the dilating electrode (see Fig. 4) may be used in the canal, with a current-strength of not more than 10 milliampères, and once in three or four days will generally be sufficient for this purpose.

The employment of elastic-wool tampons soaked in glycerin, to which is added 10 per cent. of the ichthyolate of ammonia, will aid depletion and assist in loosening adhesions. They must be carefully adjusted, so as not to exert too much pressure in the vagina where the electrode has rested in applying galvanism, or excoriation may result and interrupt further treatment.

The co-existing endometritis must not be neglected, and, as soon as the condition will permit it, active treatment of the endometrium must be instituted. Not only is this essential because it has been active in bringing about the tubal trouble which is secondary to it, but a cure of the endometritis removes a constant source of irritation, which may be instrumental in maintaining the diseased processes in and around the tubes; or, as Pozzi remarks, treatment of the endometrium places a barrier about the tubal inflammation by re-inforcing the anatomical tissue-elements in their struggle against microbes.

There is no doubt that applications of the galvanic current to the endometrium act directly upon the diseased tubes by the transmission of the current along the muscular fibres of their walls, and by removing hypertrophy of the mucous membrane at the uterine end, which may be a barrier to free drainage. A patulous condition of the uterine canal should always be preserved by applications of the negative pole with the dilating electrode, as described above, to the whole length of the canal, from external os to fundus. By directing the point of the electrode, when introduced to its full length, to either uterine cornu, the softening and relaxing effect of the current upon the tubal orifice is obtained, and the tube of that side is brought more directly under the influence of the current. That it is possible to dilate the orifice of the tube by introducing a smaller electrode into its orifice, as some have claimed to do, is a matter of much doubt; but frequently the tube can be emptied by negative applications to its orifice. This is a result that has been noted by numerous observers.

The dilatation of the tubal orifice is not so essential in this form of salpingitis, where the tube is usually permeable, as in chronic catarrhal endometritis and purulent endosalpingitis, where it is more frequently obstructed and the secretions are retained.

When there is a condition of sclerosis involving the parenchymatous structure of the uterus, it will be necessary to increase the strength of these negative applications even to 50 milliampères in order to produce any decided effect upon either the uterus or the tubal structure, but this strength should be attained by progressively increasing the strength of the application at each sitting, and never suddenly.

If the uterine canal is already patulous and there is a profuse mucous discharge, the positive pole is to be used in the uterus with the platinum sound electrode. At first the strength of the current should not exceed 10 to 20 milliampères, but it may subsequently be increased to 30 or 40 milliampères. At no time should the strength of the current employed be sufficient to produce actual pain. Nervous apprehensions should, of course, be disregarded, but if actual pain is produced and it does not subside after a few seconds the current should be reduced to a bearable point. This should be the invariable rule in carrying out the treatment of this class of diseases (tubal inflammations).

I regard the prognosis in this class of tubal inflammations, under this plan of treatment, as exceedingly good, both as to the relief of symptoms and the chance of effecting a permanent cure. The treatment is necessarily somewhat tedious, but the result will fully repay the effort if the physician and patient are sufficiently persistent.

SUPPURATIVE SALPINGITIS.

Pathology.—Suppurative or purulent salpingitis probably most always results from septic infection by direct extension from the interior of the uterus, and is to be regarded as the most serious of these inflammatory affections of the tubes.

In the first stage the mucous membrane is deeply injected, swollen, and friable. Later, the epithelium is degenerated or destroyed, and a purulent secretion covers the surface. Intense infiltration occurs, and rapidly extends to the muscular coat and subserous layer. The change that occurs in the parenchymatous structure is even more pronounced. The infiltration separates the muscular bundles, the vessels are distended, and ecchymosis occurs in spots.

The inflammation spreads rapidly to the infundibulum, and the fimbriæ become involved. At first they are swollen and the mucous membrane bulges beyond the ostium, but subsequently it contracts and folds the fimbriæ in, completely occluding the ostium and sealing the interior of the tube from the peritoneal cavity. Before this takes place septic peritonitis is very apt to occur from leakage of the purulent secretion into the peritoneal cavity. Fortunately the abdominal ostium becomes occluded very early, the effused material becomes organized, and the folded fimbriæ are agglutinated and bound to the ovary and the surrounding structures, making the occlusion permanent. Frequently, as the result of a perisalpingitis, the tube is surrounded by a mass of exudation and fixed by adhesions. This effectually protects the peritoneal cavity from infection by leakage from the tube.

If the uterine end of the tube remain patulous the tube drains into the uterus, and under favorable conditions and appropriate treatment resolution may be brought about; but this end may become obstructed as the result of inflammatory hypertrophy of the mucous membrane, and the secretion is retained within the tube, which then becomes cystic. This distension produces atrophy of the tube-walls, which become very thin if the distension is great. The obstruction of the uterine end of the tube, even in purulent endosalpingitis, is seldom permanent, and is frequently overcome by the distension of the tube allowing a discharge of the accumulated contents into the uterus.

Upon this point Bland Sutton says: "It is a fact of some interest that the uterine end of the Fallopian tube is rarely obliterated in salpingitis. Of course the tumidity of the mucous membrane would be sufficient to obstruct the passage of fluid from the tube into the uterus."

Further on he says again: "It is a fact that in the majority of distended tubes, even in severe cases of hydrosalpinx, the uterine end of the tube is obstructed, but not occluded." But the tube may become prolapsed and bent upon itself, when drainage is, of course, impossible.

This cystic distension of the tube with pus is called pyosalpinx. Pyosalpinx may become transformed into a serous cyst by spontaneous destruction of the germs, when it is designated hydrosalpinx. The tube may become distended with blood—either from retained menstrual secretion or rupture of a blood-vessel, when it is known as hæmatosalpinx.

Diagnosis.—Purulent salpingitis gives rise to a burning sensation and dragging pain in the region of the affected tube, which become exaggerated on standing or walking. Premenstrual dysmenorrhœa is frequent with menorrhagia, and septic symptoms may exist. A purulent or sero-purulent discharge from the uterus is significant, as such discharge would denote a septic endometritis, which could not long exist without involving one or both tubes. The actual condition of the tube may, therefore, be inferred if the above symptoms are present and examination elicits tenderness upon pressure in the region of either tube with thickening and enlargement. Unless the tube is distended or much enlarged, or the uterus is retroflexed, it will be difficult to establish an accurate diagnosis in some cases in an unanæsthetized patient. Rectal touch will sometimes furnish more satisfactory evidence than examination by the vagina.

Suppurative salpingitis is to be distinguished from simple interstitial salpingitis by observing that the tube is larger at one time and smaller at another. In interstitial salpingitis the tube is constantly firm and at different times the same size.

After a purulent inflammation of the tube has existed for any length of time a perisalpingitis causes agglutination with surrounding structures and fixation from effusion which has become organized, and it is frequently quite impossible to outline the tubes by palpation. The extent of this fixation is, at times, so great that the pelvic contents appear set in a plaster-of-Paris mold, this result being brought about by a pelvic peritonitis with exudation which may have had its origin in the tubal disease. Even when this condition does not exist the diagnosis is often rendered difficult on account of fixation by adhesions and exudations surrounding the parts involved, but a differentiation from other masses may be made if the uterine end of the tube, which is seldom implicated if the tube is distended, can be palpated. Therefore, when it is possible to make out that the mass is connected with the uterus by the uterine end of the tube, a mistake in the diagnosis should be comparatively rare.

If the tube become much distended it can usually be made out without much difficulty as an elongated, sausage-shaped, tender swelling, which is distinctly fluctuating. Both tubes may be involved, but frequently one side only is affected. Recurrent attacks of pelvic peritonitis are frequent, and often endanger the life of the patient.

Treatment.—Drainage of the uterine cavity, and of the tubes likewise, constitutes the chief object of treatment in purulent salpingitis. When the pain is due to distension of the tube it will be useless to employ faradization with a view of relieving it in the same manner as in the other forms of salpingitis. Evacuation of the tubal contents is the only thing that will afford relief. But if the uterine end of the tube is patulous and the secretion drains imperfectly into the uterus, it may be facilitated by the application of the negative pole of the galvanic current to the vagina on the affected side and vaginal bipolar faradization, both of which stimulate peristaltic movements in the tubes and favor drainage of the tubal contents into the uterus. In this manner such applications may afford relief of the pain. The galvanic current employed in this manner exerts another influence which is quite as important,—viz., the effect of the negative pole upon the pus-secretion is liquefying,—in consequence of which it becomes thin and drains away more readily. Moreover, when the tube is obstructed only from inflammatory hypertrophy of the mucous membrane at or near the uterine end, the galvanic current directed through it, with the negative pole in the vagina, reduces this hypertrophy and obstruction, at least temporarily, and the subsequent use of the faradic current causes a discharge of the tubal contents into the uterine cavity. The writer has often observed this, both in cases where the tubes were distended with catarrhal secretion, and with pus as well; the swelling in the tube being notably diminished afterward, and the discharge emptying into the vagina from the uterus. This has occurred in cases where previously there was a patulous condition of the uterine canal, which would have allowed the discharge to have taken place when the patient was in the erect position, and before the application was made, had the discharge been previously contained in the uterus. This, it appears to me, proves conclusively that the secretion evacuated in this manner did not come from the uterine cavity, as some have endeavored to maintain, but from beyond; and from where, if not from the tube?

When the cervical canal is patulous it is better, perhaps, to attempt to effect drainage in this manner, and, failing to do so, applications of the negative pole of the galvanic current may be made to the endometrium. This method of application probably exerts a more direct effect upon the tubal mucous membrane on account of its continuity with that of the uterus, with which the electrode comes immediately in contact. The strength of the current in vaginal applications may vary from 20 to 50 milliampères, employed for a period of five minutes, and repeated every second or third day. As there is degeneration of the endometrium, the use of the current in sufficient strength to produce cauterization and destruction of the morbid process is not objectionable, though it must be very cautiously done. Moreover, the eschar resulting from cauterization with the negative pole does not contract and produce stenosis. In

the beginning galvanic applications to the endometrium must be made cautiously when there is a purulent accumulation in the tube, and not more than 10 milliampères should be employed until tolerance of an increased strength is shown. Likewise care must be observed not to employ the galvanic applications when there is any indication of an acute inflammation in or around the tubes. If the cervix is not patulous the negative dilating electrode (Fig. 4), with a current-strength of 10 milliampères, may be introduced once in two or three days, and the vaginal galvanic applications continued.

The application of the positive pole to the vagina or to the cavity of the uterus I do not regard as permissible when pus-accumulation in the tube is known to exist. Apart from the astringency induced and the contracting effect upon the tissues in the vicinity of this pole, the osmotic action of the current (if it may be so styled) in the direction from the positive to the negative pole would probably influence absorption of the purulent secretion and prove detrimental.

No doubt much of the benefit derived from these galvanic applications to the uterine cavity in tubal affections is due to its curative power over the endometritis, which is effected by cauterization of the diseased surface and alteration of the submucous structures. An electrode should be employed for this purpose that will include the endometrium from external os to fundus, because the whole extent of the uterine cavity is involved in the morbid process, and because a greater strength of current can be employed with less discomfort. Moreover, a greater extent of surface-contact distributes the interpolar influence of the current and minimizes the local action, which is sometimes advantageous.

Apostoli and Gautier, as well, have emphasized the diagnostic significance of the intra-uterine intolerance of strong galvanic currents as indicative of tubal disease; and though both of these gentlemen, as well as Charlet, Brösse, La Torre, Slavjensky, Prochownick, and many others, have employed galvano-caustic applications (as they style them) to the endometrium with great satisfaction in tubal affections, they are particular to specify that moderated intensities only should be utilized, and in conditions uncomplicated by active inflammatory action, in the vicinity of the appendages.

These applications have for their object the attainment of exactly the same end as that claimed by Polk for the method he has so ably and strenuously advocated, viz., dilatation, curettement, and drainage with gauze, which effects depletion. Essentially the same thing is accomplished by dilatation with the negative pole; negative cauterization of the endometrium removes the diseased mucous membrane and secures depletion, with drainage of the uterine cavity and Fallopian tubes. It cannot be said that a cure can always be effected as rapidly by the method herein advocated as claimed by Polk for his method, but the

result is just as certain, though a little more tardily accomplished, and the dangers incident to the other method are avoided.

That purulent accumulations in other localities are permanently removed by free drainage is quite certain; then, why cannot the same result be anticipated here? The fact is, that many of these cases of purulent salpingitis are cured, and remain permanently cured; and it is by no means necessary to regard removal of the diseased structures *in toto* as essential for cure, or even to avoid the dangers of an impending fatal issue, which is said by certain operators to be constantly menacing the patient who refuses or delays operation. The operation does not cure, though it may remove diseased parts, which may be bottled and preserved as evidence of a cure. Frequently the patient is left in a worse condition than before, being deprived of important organs which nature has seen fit to provide and endow with functions which are essential to a useful, happy, and healthful existence. Moreover, removal of one diseased organ does not cure the disease in the whole, and those remaining are not favorably affected by the operation. An endometritis, especially a purulent type of inflammation, is frequently a source of as much suffering as diseased appendages, and will persist and give trouble after the appendages are removed. Coupled with these objections is the extreme liability to the adhesion of the stump to adjacent tissues, which frequently introduces a new phase of suffering, oftentimes tenfold worse than that for which relief was first sought.

I do not contend that the operation is never necessary, nor that all the risks and uncertainties are not sometimes to be disregarded, in view of the future well-being of the patient. Yet the operation is done very much too often, and without due consideration of the possible ultimate results, and without representing its disadvantages as well as its advantages squarely to the patient, and without previous efforts to overcome the apparent necessities for a radical operation by every known means. In some of those cases where the tubes are agglutinated and surrounded by exudation the vaginal applications of the negative pole of the galvanic current, with a strength of from 30 to 50 milliampères, augmented by bipolar faradization of the vagina, will afford marked relief of the pain, loosen the attachments, promote absorption of the exudate, and restore mobility. The applications are to be repeated every second or third day, and if drainage from the uterus is good the interior of the uterus should not be interfered with until comparative mobility is secured and sensitiveness has been overcome.

When the cervical canal is not patulous, however, an occasional negative application, with the copper sound curved so as to permit its introduction without pain, may be cautiously made. The dilating electrode, which would distend the canal, might provoke injudicious irritation if used in this stage. Not more than 10 milliampères should be used for two or three minutes.

When sensitiveness to vaginal pressure has, in a measure, been overcome and comparative mobility has been secured, the endometrium is to be submitted to treatment with the negative pole, with a current-strength which may vary from 20 to 40 milliampères, used for five minutes every third or fourth day. Bipolar faradization of the vagina may be continued with advantage.

In that condition where all the pelvic organs are fixed by exudation resulting from a pelvic peritonitis, as soon as the acute attack has subsided, bipolar faradization combined with positive vagino-abdominal or lumbar galvanism, at first with a current-strength of 30 to 50 milliampères, will relieve the pain and congestion. When this much has been accomplished absorption of the exudate may be facilitated by negative vagino-abdominal or lumbar galvanism (30 to 60 milliampères) for five minutes every second or third day. Bipolar faradization of the vagina may be employed also in conjunction with the negative galvanic applications to allay pain if necessary at any time.

Gautier,[1] voicing the opinions of Apostoli, regards with much favor the intra-uterine negative applications in the treatment of salpingitis. He says, "I advise in suppurative salpingo-oöphoritis (non-encysted) the employment of the negative intra-uterine galvano-caustic chemical in a dose of 20 to 80 milliampères, because I have confidence in its denutritive and revulsive action. It favors the escape of pus into the uterine cavity, rapidly relieves congestion of the appendages, and quiets the pain. But it is necessary to understand that it may be dangerous if the tube is impermeable and does not permit the escape of pus, or if the inflammatory condition is too near the acute stage. Also, without doubt, it is necessary to abstain from all violent measures, especially at the beginning of the treatment, to proceed with extreme caution, and to increase the dose gradually. These conditions being observed, the harmlessness of the method is assured. It is essential to observe that the tolerance of the current is evident and increases with the number of applications. The escape of pus occurs sometimes at the first and often at the third *séance.* This is effected by the natural channel (through the uterus), producing rapid improvement, which increases and persists. When, however, the pains continue; when the general condition is aggravated; when the digestive disturbances increase; when, in fact, the patient does not tolerate the treatment without nausea and sharp pains in the hypogastrium, we must suspect a collection of pus which cannot thus be evacuated."

In such a condition he advises a resort to surgery. He repeats the observations of Apostoli upon the intolerance of the uterine cavity in fibromata when the appendages are affected, and utilizes it as an aid in diagnosis.

[1] Revue International d'Électro-Thérapie, vol. ii, pp. 33, 35, and 38.

HYDROSALPINX.

When the tube is distended with serum it is generally found behind the cervix, at the bottom of Douglas's pouch, in the form of a smooth, tense, elastic, fluctuating, oval mass, and may or may not be adherent, according as there has or has not been a previous pelvic inflammation. According to Thomas (sixth edition) hydrosalpinx is not a serious affection, seldom endangers the patient's life, and can usually be cured by aspiration or incision by way of the vagina, with irrigation and drainage.

A few years since the writer advised a method of dealing with these serous sacs which he designated galvano-tapping, that is, aspiration, with subsequent application of the galvanic current to prevent refilling, which has been eminently successful. The method was suggested to him by the success attained in the treatment of hydrocele, by applying the negative pole of the galvanic current through the cannula after withdrawal of the fluid. In none of the cases so treated has the fluid been reproduced. Applying the same idea to the treatment of hydrosalpinx, he devised a trocar and cannula (shown in Fig. 6) by means of which the fluid could be withdrawn after penetration of the sac and removing the trocar, and the current could be applied through the cannula as an elec-

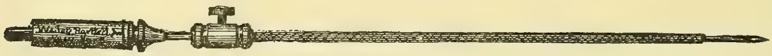

Fig. 6.—Goelet's Cannula Electrode. Silver Cannula with Trocar and Adjustable Sheath for Aspirating Hydrosalpinx.

trode, since it is protected by an insulated sheath from contact with the vagina. The cannula is small, penetrates easily, and the insulating sheath can be adjusted, by means of a set-screw, so as to limit the extent of penetration to any degree desired. The method of application is as follows: Having fixed the degree of penetration, the point of the trocar is drawn within the cannula to avoid wounding the vagina or the finger along which the instrument is introduced as a guide. The vagina and vulva are rendered thoroughly aseptic by a douche of creolin or lysol solution, the index finger is introduced into the vagina against the most dependent or prominent portion of the sac, which is held firmly in position by pressure from above on the abdomen (this will not be necessary if the sac is already fixed by adhesions), and the instrument is introduced along the finger and plunged into the sac. Withdrawing the trocar the fluid will usually flow out readily, or drain away slowly, allowing the sac to collapse; but if it does not an aspirator may be attached, and, where deemed advisable, the sac may be irrigated with an antiseptic solution through the cannula, though this is rarely necessary when the sac contains only serum. The negative pole of the galvanic battery is now connected with the cannula, the positive with a large clay electrode on the abdomen, and a current of 20 to 40 milliampères is used for five min-

utes, when the current is turned off and the cannula withdrawn. A loose wad of iodoform or aristol gauze is placed against the wound in the vagina, and the patient is placed in bed, where she should remain for several days or a week, as necessity demands. The gauze is replaced every day.

It is best to perform this operation under an anæsthetic, because the patient can be better controlled and the application is sometimes painful. It should always be done at the patient's house, and never at the office of the attendant. Usually the operation is only followed by a slight aching in the pelvis for a few hours; but there is no rise in temperature, and by the following day the patient will desire to get up. It is wiser, however, to confine her to bed for a few days. There has been no re-accumulation of the sac-contents in those cases which I have operated upon in this manner, but subsequent treatment, which will be suggested by the condition of affairs in the pelvis, may be necessary. This may not always be possible, and future developments may, of course, cause a repetition of the same condition.

In using the current through the cannula as an electrode, it is brought directly into contact with the interior of the collapsed sac, which the instrument must penetrate before the fluid can be withdrawn. It has been suggested to use the current before withdrawing the fluid, so as to insure the action of the current through the medium of the fluid as a conductor upon the whole interior surface of the sac; but the objection to this is that the greater diffusion of the current would moderate the local action, which is, I think, accountable for the good results obtained. This method is applicable to any-sized hydrosalpinx which can be reached and aspirated by the vagina, when fixed by adhesions, in the absence of anything contra-indicating the use of the current.

HÆMATOSALPINX.

If there is occlusion at the uterine end blood may accumulate in the tube as the result of repeated effusions from the tube-walls during menstruation, rupture of a blood-vessel in the tube-walls, or rupture of a Graafian vesicle, the tube being adherent to the surface of the ovary, preventing escape into the peritoneal cavity. It is usually confined to the ampulla and, if only moderate in quantity, may be absorbed before permanent dilatation of the tube occurs; but repeated effusions resulting from a catarrhal process, induced by the presence of the primary hæmorrhage, may cause considerable distension. There may or may not be adhesions between the tube and adjacent structures. When dense adhesions resulting from a perisalpingitis surround the distended tube rupture is not so frequent as is generally supposed, and when it does occur it is more often due to manipulations than natural causes.[1] The blood retains its fluid character indefinitely, which has been attributed

[1] Coe, in American System of Gynæcology.

by Klebs to the peculiar influence of the tubal secretions. The condition is, fortunately, rare, being observed by Winckel only four times in two hundred cases of tubal disease. The mass usually projects downward against the vaginal surface, when it is within easy reach; but, unfortunately, it sometimes extends upward beyond reach in the vagina.

Thomas advises laparotomy when the tumor is probably intra-peritoneal (high up), but if it point downward and is between the layers of the broad ligament, which may be suspected if it be low down and immovable, aspiration, incision, and drainage through the vagina, he thinks, offer better prospects than laparotomy. Before deciding upon the course of treatment to be adopted, the possibility of a tubal pregnancy, which may be confounded with this condition, must be excluded.

Since it is admitted that moderate accumulations of blood in the tube are often absorbed and give no further inconvenience, it is obvious that galvanism employed in a manner to favor this end would be appropriate. Reference to the method of treatment suggested for hæmatoma will afford an explanation of the mode of action of this agent upon blood-extravasations. The object being to arrest and control the effusion or hæmorrhage when it is discovered to be continuous, the positive pole must be employed against the mass in the vagina with the clay-covered carbon-ball electrode. The clay pad, placed low down on the abdomen, is connected with the negative pole, and the vaginal electrode is placed under the mass so as to include it directly between the poles. Fifty milliampères used for five or ten minutes every second day will usually be sufficient to effect the desired purpose. When necessary, however, the strength of the current may be increased with benefit, if care is taken to dip the electrode into egg-albumen previously to avoid the local action upon the vaginal surface. The current stimulates osmotic action from the positive to the negative pole, and thus absorption of fluid accumulations is effected. It is also possible that the lymphatics are rendered more active under the stimulus of the current.

When the accumulation produces considerable distension, threatening rupture, and the mass is low down, within easy reach through the vagina, it should be aspirated with the trocar and cannula, made of platinum (see Fig. 7), in the same manner as described in dealing with hydrosalpinx. This is rendered possible because of the fluid character of the retained blood. But when it is too thick to be emptied with this instrument a cannula of larger size may be used, or, after withdrawing a portion of the fluid, an antiseptic solution can be injected through the cannula to dilute it and facilitate its removal. (Lysol will answer the purpose very well.) Before withdrawing the cannula it is connected with the positive pole of the galvanic battery (the negative being placed upon some indifferent part of the body, either on the abdomen or over the sacrum) and 30 to 50 milliampères used for five minutes.

Subsequent drainage will usually be unnecessary if thorough anti-

septic precautions have been observed in doing the operation. The application of the positive pole through the cannula, which is permitted because it is made of platinum, causes contraction of the dilated sac. Subsequently, positive galvanic applications with the ball electrode in the vagina will promote resolution. Where deemed advisable, a small quantity of solution of iodide of potassium (1 to 10) may be injected through the cannula into the sac before the application of the current, which will become decomposed under its action, setting free the iodine, and very effectually distributing it over the interior surface. But when this is done, it will be well to leave a patulous track where the cannula penetrates for future drainage.

If the tumor is intra-peritoneal and situated high up beyond reach, and the distension threatens rupture, laparotomy will undoubtedly be indicated, and should not be delayed. It is then, probably, not within the range of any beneficial action from the interpolar action of the current, and its rupture into the peritoneal cavity might be disastrous. Let it be clearly understood that we are not advocating hazardous, but conservative measures; and laparotomy here is to be looked uoon in that light.

PYOSALPINX.

When the uterine end becomes obstructed in a tube the seat of suppurative inflammation the secretions are retained, and sometimes considerable distension occurs. The abdominal ostium becomes occluded early, and prevents escape into the peritoneal cavity. The distension may be permanent, or the tube may partially empty itself into the uterus periodically, when the distension is sufficient to overcome an incomplete obstruction or amelioration of the diseased condition causing the obstruction at the uterine end allows this to take place. Usually the tube is buried in a mass of inflammatory exudation or confined by adhesions resulting from recurring attacks of local or pelvic peritonitis, and is situated close to the vaginal wall, behind the cervix, in Douglas's pouch, or a little to one side. This state of affairs, though productive of intense suffering at times, precludes the probability of rupture into the peritoneal cavity, and may exist for some time without giving rise to any very serious symptoms. (Thomas.) Apart from the inconvenience caused the patient from the pain it induces, and the injurious effect upon the system from the absorption of the retained pus, the recurring attacks of pelvic peritonitis demand that immediate steps be taken for its relief.

About three years since the writer suggested a method of dealing with some of these cases which was intended to avoid the necessity of removal by laparotomy, with its attendant risks and uncertain consequences, relating cases thus treated with successful results. It is not claimed that this method of treatment is appropriate in all cases, and,

while advocating it as a conservative measure, I desire to be understood as in no measure opposed to a justifiable laparotomy at any time; in fact, I resort to that operation promptly when, in my judgment, it is demanded. But if a pus-tube is low down, within easy reach through the vagina for aspiration, and adherent, it is far safer to empty it and apply the galvanic current through the cannula for the destruction of the pyogenic membrane than submit the patient to the dangers of a laparotomy, to say nothing of the ultimate consequences of the radical operation.

In the last edition of his book Thomas says of the treatment of pyosalpinx: "If the pus-tube is situated deep in Douglas's pouch, is firmly adherent there, is easily reached through the vagina, and the appendages of the other side are apparently normal, the propriety of opening and draining the abscess through the vagina may be well entertained." He claims to have treated a number of cases in this manner very successfully. In a conversation with the writer recently he declared his preference for this method of treatment in certain cases of pyosalpinx, because it offered better prospects for the patient than laparotomy.

In a paper entitled "The Conservative Treatment of Inflammatory Diseases of the Uterine Appendages, etc.," read by invitation before the Philadelphia Obstetrical Society, January 2, 1890, the writer outlined his method of dealing with certain cases of pyosalpinx, which had been announced in a previous contribution in the *New York Medical Journal* in June of the year previous.[1] This method, which has been designated galvano-tapping, is essentially the same as the aspiration practiced by Thomas. The only difference is that he, in some instances, makes a free incision and inserts a drainage-tube; and in the method under consideration electricity is employed after aspiration instead, the necessity for a drainage-tube being thereby avoided. Thomas acknowledges that one objection to the method he advocates is, that a fistulous track often remains, and there is a prolonged discharge, lasting sometimes for several months.

When the distended tube is low down, within easy reach through the vagina, whether it be firmly adherent or not, this method of treatment may be carried out; in other words, if a tube will bear aspiration, the method can be employed. Ordinarily a distended tube that is not adherent can be drained into the uterus, and aspiration is not necessary; and, when it is possible to effect drainage through this channel, it is best to do so.

The cut shows the platinum cannula-electrode (No. 4, French catheter scale) for the galvano-tapping of pyosalpinx through the vagina. The shaft is covered with an adjustable sheath, *A*, of hard rubber for insulation. This may be fixed at any point by the screw, *B*, and the

[1] M. Gautier, of Paris, has done me the honor to mention this method with favor in a communication at the recent Congress for the Advancement of Science held at Marseilles.

degree of penetration limited. At *C* there is a three-way stop-cock, and at *D* a connection for an irrigator, as well as a socket for connecting with the battery. When the trocar, *F*, is withdrawn, an aspirator may be attached to the rubber tubing, *E*, and, after the pus has been drawn off by a quarter turn of the stop-cock, *C*, the cavity may be flushed with an antiseptic solution passing in at *D* through the cannula. By turning the stop-cock straight again the fluid is allowed to escape through the tubing, *E*, into the aspirator-bottle. Care must be observed not to over-distend the Fallopian tube, the walls of which have been much weakened in some cases. That I may not be misunderstood, I will say that I limit the degree of penetration usually to one centimetre, and deem the procedure appropriate only when the tube is close to the vaginal wall, full and tense, demanding immediate interference.

The aspirating cannula, which is made of platinum (see Fig. 7), is introduced in the same manner as described in the treatment of hydro-salpinx, under strict antiseptic precautions; the pus is withdrawn, and the cavity irrigated with an antiseptic solution. The cannula is arranged with a two-way stop-cock, which allows this to be accomplished readily, but care is necessary, when the tube is not adherent, to prevent leakage

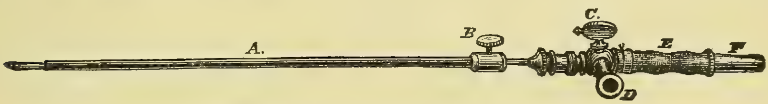

FIG. 7.—GOELET'S PLATINUM CANNULA-ELECTRODE.

into the peritoneal cavity. The solution should flow from a reservoir of moderate elevation, and much distension of the sac must be avoided. The stop-cock turned in one direction allows an in-flow, and a quarter turn in another direction an out-flow, so that thorough irrigation is possible. The penetration of the cannula is limited by the insulating sheath and a set-screw. It is arranged to allow a penetration of one centimetre, but half a centimetre is usually sufficient.

Before withdrawing the cannula it is connected with the positive pole of the galvanic battery, and a current-strength of 50 milliampères is used for five minutes. This pole is preferred because of its well-known antiseptic properties, which is due to the liberation of oxygen and chlorine. Its peculiar reaction destroys the character of the pyogenic membrane and promotes resolution in the sac-walls and surrounding structures. The cauterization of the track of the cannula shuts it off from the tissues which are penetrated, whereby extravasation and absorption of septic material are prevented. When the tube is not adherent the peritoneal cavity is penetrated, but the subsequent cauterization induces an immediate adhesion of the peritoneal surfaces around the puncture, which effectually closes it from outside influences of an injurious nature. Sufficient drainage will ordinarily be afforded through

the puncture-track, but, when necessary, it may be facilitated subsequently by passing a small probe or sound-electrode connected with the negative pole to enlarge the track (10 to 15 milliampères will be sufficient). This operation should be performed only at the patient's house, and she should be put to bed immediately after. A loose dressing of iodoform or aristol gauze is placed in the vagina, and renewed every day or two, when a hot douche of a 1-per-cent. solution of creolin is given.

Gautier advises injecting a solution of iodide of potassium (1 to 10) into the sac after evacuating; then he employs the positive pole of the galvanic current through the cannula as an electrode with 50 to 80 milliampères for five or ten minutes. The current decomposes the solution, and iodine is set free within the sac. An exit for subsequent drainage will be necessary.

Apostoli advises negative puncture by the vagina, which creates a fistulous track for subsequent drainage of the distended tube by this channel, and keeps the vagina packed with iodoform gauze.

When the tube is sacculated and there is no connection between the different cavities, each tumor which projects against the vaginal wall may be aspirated in like manner. It may be argued that emptying the abscess does not cure the diseased tube. This may or may not be true, according to the condition. Many very bad-looking abscess-cavities in other parts of the body are frequently cured permanently by simple aspiration and drainage. Then, why not here?

The main advantage in favor of this method over that of incision and drainage is that there is no delay in the closing of the fistula, and no prolonged discharge lasting for months. The discharge from the pyogenic membrane is immediately arrested by the action of the current and usually no drainage follows, unless the iodide-of-potassium solution is used.

The subsequent management of the case and the treatment necessary will be suggested by the condition remaining after evacuation of the abscess. Galvanization with the positive pole in the vagina will promote resolution of the surrounding structures, and the negative pole may be employed to hasten the absorption of deposits or soften and relax adhesions which interfere with the necessary mobility of the pelvic organs. Treatment of the co-existing endometritis must not be neglected. It is seldom possible to restore an absolutely normal condition; nor is it attained by the other alternative,—laparotomy,—but a condition quite conducive to health, comfort, and usefulness may be brought about. Can as much be said of the radical operation, which deprives the patient of organs essential alike for her usefulness and happiness?

OVARITIS.

Ovaritis rarely exists as a distinct affection, and probably is most always associated with and secondary to salpingitis. For this reason most authorities have preferred to consider them under the general head of salpingo-oöphoritis. Pozzi doubts the occurrence of primary ovaritis, but Prochownick and Dalché have recently upheld the view that it may occur independently of infection or any preceding lesion of the uterus and tubes. That ovaritis may and often does exist independently of salpingitis the writer firmly believes, or the latter condition, if present, may be so obscured as to give rise to no evidence of its existence.

Etiology.—The acute form may occur coincidently with acute salpingitis, being produced by the same causes, such as disturbance of menstruation arising from cold or unusual exercise, pelvic peritonitis, septic infection following parturition, or from gonorrhœa by direct extension from the uterus and tubes, or it may occur in the course of the acute zymotic diseases.

A condition of hyperæmia which is sometimes regarded as an inflammation frequently occurs as the result of imprudence during menstruation, too frequent and excessive coition, ungratified sexual excitement, constipation, etc. Structural changes characteristic of chronic inflammation may result from the acute stage, but chronic ovaritis does not often follow the acute process. Most frequently it begins insidiously and develops gradually from this condition of hyperæmia.

A frequent cause of chronic ovaritis is undoubtedly interference with the circulation and nutrition produced by displacement of the uterus, and also from adhesions surrounding the organ resulting from tubal disease. Backward displacements of the uterus drag the ovaries out of their position in the pelvis and render them more susceptible to direct injury during intercourse, and to constant irritation from constipation. Prolapse of the ovary is both a cause and an effect of enlargement due to chronic inflammation.

Pathology.—The acute state is characterized by congestion with enlargement, and the inflammatory process may be follicular or interstitial, or the two may be combined. In the follicular form the epithelium is alone involved, and degenerated. In the interstitial form the stroma of the ovary is involved and becomes infiltrated with serum and leucocytes, and the connective-tissue cells are increased.

Chronic ovaritis may exist as a condition of atrophy, hyperplasia, or cystic degeneration; but the term is most frequently applied to a condition of passive hyperæmia, which may eventually result in a state of hyperplasia.

In the atrophic form the ovary is small, hard, and nodular, and the tunica albuginea is thickened.

In the hyperplastic variety it is enlarged, hard, and smooth. It is this form usually which is found prolapsed from its increased weight.

In the cystic variety the stroma, as well as the follicles, is involved, and it is known as cystic degeneration, the surface of the ovary being studded with minute cysts. The ovary is usually enlarged, and presents a somewhat uneven appearance from the projection of the cysts above the surface.

Diagnosis.—It is sometimes exceedingly difficult and frequently impossible to diagnose acute ovaritis from acute localized peritonitis or acute salpingitis. There may be sharp pain in one or both ovarian regions, radiating to the back, and aggravated by standing, walking, and defecation. As distinguished from that of peritonitis the pain is more neuralgic in character, and is apt to be associated with pain in the thigh of the corresponding side. Sympathetic pains in the breasts are frequent, and painful menstruation is common. If the pain is strictly unilateral and localized in the ovarian region it may be regarded as significant, but it may indicate a peri-oöphoritis or salpingitis as well. Physical examination, unless the patient is anæsthetized, would be useless, and the administration of an anæsthetic in the acute stage merely for the purpose of diagnosis is questionable, since the treatment would be practically the same for any of the conditions with which it is apt to be confounded.

In that form characterized by hyperæmia, and also in the chronic form, the symptoms are usually less marked than in the acute form. A dull, aching pain, increased by walking or standing, which is referred to one or both ovarian regions (the left more frequently), is complained of. There may be pains radiating down the thighs, in the hip and rectum, and sympathetic pain in the mammæ. Intercourse is sometimes painful, especially if the ovary is prolapsed. Defecation is usually painful, and is sometimes followed by a feeling of exhaustion. There is a marked tendency to hysteria. Menstruation is irregular and painful. A peculiar feature about the dysmenorrhœa of ovaritis is that it is apt to precede or follow the menstrual discharge. Menstruation is often followed by a feeling of exhaustion, lasting for several days or a week. Sterility is common.

Physical examination, if the patient is thin and not too sensitive, will reveal the enlarged ovary very sensitive to the touch, either at the side of the uterus or, if prolapsed, at one side of Douglas's pouch. Pressure upon it gives a sickening sensation. Examination under anæsthesia will allow a much more satisfactory diagnosis.

Ovaritis is to be distinguished from salpingitis with tubal distension by the enlargement being more globular in shape and lying farther from the uterus, and there is no fluctuation unless there is an abscess.

From exudation in the broad ligament ovaritis may be differentiated by the enlargement being more circumscribed, less closely related to the vaginal vault, and there is less fixation of the uterus.

An enlarged ovary may be mistaken for a small, lateral fibroid of the uterus or fibroid of the ovary or tube. It is distinguished, however,

by being softer and more sensitive to pressure, and it gives rise to more annoyance.

Fæces in the rectum may be a source of some confusion, but enlargement due to this cause usually indents upon pressure, is not sensitive, and disappears upon emptying the rectum.

Treatment.—In the acute stage vaginal bipolar faradization with the current of tension, applied in the same manner and under similar observances as described for acute salpingitis, affords marked relief of the pain and congestion, acting in the same manner as does faradization for orchitis. Perfect quiet in bed must be enjoined, and the treatment must be given at the bedside of the patient. The bowels must be kept relaxed. But unless every precaution is taken in carrying out the details of the application, and unless a proper current is selected from a suitable apparatus, electricity will prove not only unsatisfactory but absolutely objectionable, and possibly harmful, by provoking increased pain instead of relieving it. In the chronic form and that of hyperæmia of the ovary, pain must first be relieved by the systematic employment of vaginal bipolar faradization, which will consist of daily applications of the current of tension, according to the directions laid down under the treatment of salpingitis. The first application, if the qualities of the current are appropriate and it has been properly administered, will give prompt relief, which will continue for hours, and after the third or fourth application it will usually be possible to make palpation for diagnostic purposes, where it could not have been done before without general anæsthesia. It is not intended to convey the impression that the pelvis is always rendered positively insensitive to digital manipulations, though this result is sometimes obtained, but sufficient local anæsthesia can be induced in all cases where there is no acute inflammatory process or abscess formation to permit a satisfactory examination.

The relief afforded by electricity employed in this manner is just as certainly permanent as that afforded by opium or any other sedative, if the exciting causes which are active in giving rise to the pain and congestion are removed.

Sedation is brought about by the faradic current of tension, by effecting a temporary paralysis of the sensory and motor nerves. Agitation of the constituent elements of the nerve-fibre by the rapid succession of vibrations produces an annulment of its capacity to conduct pain impulses.[1] The relaxation which follows the continued tetanic contractions, induced by the rapid succession of impulses imparted to the muscular fibres, relieves the painful contractions of surrounding muscles, and the stimulus exerted by the current upon the capillaries relieves congestion by removing blood-stasis.

In the beginning a current must be employed which will soothe without stimulating, and for this purpose the longest and finest wire coil

[1] Morton, in Goelet's Electro-therapeutics of Gynæcology.

should be employed until it ceases to be effective, when a shorter coil may be substituted. For instance, the current from the coil of No. 36 wire, fifteen hundred yards long, will furnish a current suitable for acutely-sensitive conditions; but as this becomes subdued it will be necessary to use the current from one thousand yards of the same-size wire, and later that from five hundred yards,[1] or the coil of No. 32, eight hundred yards long. The current is thus rendered progressively more stimulating, which is necessitated by the benumbing effect of this current of high tension and the insensitiveness the use of this current induces. In some instances this change will be required in one sitting; at other times several separate applications may be made without changing the character of the current. Very much will, of course, depend upon the judgment and experience of the operator. Employed properly, this current will positively afford the relief promised, and disappointments may be attributable to disregard of technique, unsuitable apparatus, or perhaps a mistaken diagnosis.

The applications should be prolonged from fifteen to thirty minutes, or until absolute sedation and relief of pain are secured, and they should be repeated every day until relief is prolonged sufficiently to allow perfect comfort under ordinary conditions for a period that will warrant an extension of the interval to two days. This treatment must be persisted in until permanent relief of the pain is obtained and the sensitiveness to digital pressure has been overcome.

Ordinarily galvanism should not be employed until the sensitiveness to pressure has, in a great measure, been subdued. Then the positive pole may be used against the ovary in the vagina with the carbon-ball clay-covered electrode (see Fig. 3), the negative being attached to a clay pad placed over the hypogastrium or over the sacrum. The latter location for the external electrode is preferable for the reason that the nerve-supply of the ovary is from the inferior hypogastric plexus, situated at the side of the vagina and rectum, which in turn is derived from the hypogastric plexus of the sympathetic, situated in front of the promontory of the sacrum.

The strength of the current should at first be only 20 or 30 milliampères, continued for eight or ten minutes, and later perhaps 40 to 50 milliampères for five minutes. The galvanic applications should be followed by vaginal bipolar faradization for ten or fifteen minutes, and they may be repeated every second or third day.

The permanency of the result secured will depend in a great measure upon the avoidance of all sources of irritation which tend to bring about a relapse. It is quite certain that it is frequently impossible to afford even temporary relief if the constant irritation of a loaded rectum is overlooked; and, for this reason, to avoid disappointment, the bowels

[1] This result can only be attained by employing the arrangement of coils suggested by the writer.

should be freely emptied before every application. Likewise the removal of the other causes which have been active in establishing the condition should, when possible, be removed or avoided.

When the ovary is prolapsed much benefit will accrue from the support of a carefully-arranged tamponade of the vagina, when it can be endured without too great discomfort. This will be especially serviceable when retroflexion of the uterus exists as a complication.

The great majority of these patients suffering from chronic ovaritis and ovarian neuralgia can be restored to a life of comfort, happiness, and usefulness by the plan of treatment outlined, and unless degenerative changes have taken place in the structure of the ovary a radical cure may be effected and the sterility overcome. Can as much be said of other methods of treatment?

When structural changes have occurred, such as atrophy or cystic degeneration, the prognosis is not so favorable, but very much can be accomplished by the methodical application of the galvanic current, especially when a condition of hyperplasia exists. If these conditions can be diagnosticated and differentiated from each other, the current can be adapted to suit, and the treatment will result in some degree of satisfaction; but where this is not possible it must be regarded in great measure as empirical, and success, when obtained, must be considered accidental.

In the atrophic variety the negative employed as the active pole against the ovary in the vagina, and the external electrode placed over the solar plexus so as to bring the blood-supply of the ovary under the influence of the current, would be productive of the best result. At the same time the menstrual function, which is apt to be deficient, should be stimulated by appropriate applications to the uterus of both the galvanic and faradic currents. In selecting the appropriate faradic current for this condition to be used in the vagina it must be remembered that stimulation is more to be desired than sedation; consequently the current should be applied with this end in view. It will not be necessary, or even advisable, to stimulate to the extent of producing irritation or provoking discomfort,—as, for instance, by employing the current from the coarse-wire coil,—but a proper manipulation of the fine-wire current will effect the desired result. The current of tension can be rendered highly stimulating without being irritating by increasing it rapidly; that is, by maintaining the strength of the application throughout the *séance* at a point where it is constantly experienced by the patient, and never allowing a condition of relaxation to be produced.[1]

In the hyperplastic variety the positive should be the active pole placed against the ovary in the vagina. The external electrode (negative) should be placed over the lumbar region. Bipolar vaginal faradization with the current of tension should be employed for the relief of pain and to aid in removing the surrounding congestion. When the

[1] See The Electro-therapeutics of Gynæcology, by the writer, vol. i, p. 95.

ovary is bound down by adhesions or surrounded by exudation the negative pole should be employed as the active pole in the vagina instead of the positive, and the faradic applications used in conjunction will facilitate absorption and render vaginal tampons (which may be essential) more readily tolerated.

When the ovary has undergone cystic degeneration the use of the positive pole against it in the vagina, with a current of maximum, not minimum, strength, should be just as effective as against cystic degeneration of the uterine cervix; and all who have had much experience with this agent in the treatment of those conditions know how promptly the positive pole acts upon the diseased surface. Mild applications will not be effective, but the stronger applications will not be well borne at first. Commencing, however, with 30 to 40 milliampères every second or third day, and gradually increasing to 50 and 60 milliampères, and lengthening the interval as the strength of the current is increased, from 80 to 100 milliampères can after awhile be employed once a week. Some discomfort may be produced, but this will promptly subside upon using bipolar faradization and compelling sufficient rest in the horizontal position. Bipolar faradization may likewise be employed with advantage in the interval. The external electrode should be placed over the lumbar region or sacrum.

The unipolar application of the faradic current (one pole, positive, in the vagina and the other over the lumbar region) will, in some instances, give better results than the bipolar method in these conditions of ovarian irritation and engorgement, and when the other method is not entirely satisfactory this should be tried.

Morton's secondary static induced current (from the outside coating of the Leyden jars) may be employed in the same manner as the faradic current, and with the bipolar electrode in the vagina for the relief of pain. The vibrations may be established by first approximating the balls attached to the sliding rods connected with either pole of the machine and gradually separating them, or these balls may be widely separated and the pistol device may be introduced in the secondary circuit, and the interruptions made by gradually separating two small brass balls attached to it, which make a break in the circuit.

The static spark (indirect), by producing a revulsive effect upon the surface, applied to the hypogastrium of the affected side, will sometimes afford great relief of the pain, and may be employed when the internal applications are objectionable.

I may be accused of claiming too much for electricity in conditions which many contend are relieved only by removal of the diseased organs, but that all authorities are not agreed as to the incurability of ovarian disease is quite certain. For instance, Winckel says, "The operator who extirpates an ovary merely because of painfulness and hyperæsthesia commits a scientific error." Schröder states that non-operative

treatment of ovaritis is by no means so hopeless as has been represented by many. And Liebermeister declares it a blunder to remove ovaries which are not obviously diseased.

CHRONIC PERI- AND PARA- METRITIS; POST-INFLAMMATORY PELVIC DEPOSITS.

Under this head are comprised exudations in the vicinity of the uterus and involving the appendages, resulting from pelvic peritonitis, pelvic cellulitis, or perisalpingitis. It seems appropriate to include them with diseases of the appendages, since they are so frequently a consequence of tubal and ovarian disease. The condition may vary from a localized deposit on one side of the uterus to a state of complete fixation of the entire contents of the pelvis, where everything is firmly matted together and consolidated by extensive exudation involving the whole cavity covered by the pelvic peritoneum.

It is often impossible clinically to separate the results of inflammation involving these different structures and declare that the condition is due to the one or the other independently, and such a distinction, in so far as the treatment is concerned, is quite unnecessary. The differentiation is only important when the condition is sharply defined, in estimating the probable result to be obtained from treatment, and in determining how much local interference is permissible. A distinction is frequently only possible by reference to the cause, since some authorities believe that cellulitis only occurs from septic absorption, as the direct result of some violence done the cervix,—as laceration,—either from abortion or labor; hence it would seldom be found in a woman who has never been pregnant. However true this may be, it is certain that an extensive inflammation of the cellular tissue never occurs without more or less involvement of the pelvic peritoneum and *vice versâ*, and for this reason the two conditions are often so intermingled as to render a distinction impossible. It is probable that the location of the inflammatory product furnishes the best clue to the seat of the acute process. For instance, the exudation from a parametritis is more apt to be found to the side of the uterus near the cervico-vaginal junction, and in the folds of the broad ligament, where the cellular tissue abounds; whereas, the deposit of perimetritis is more frequently to be found posterior to the uterus.

Early recognition of the nature of the deposit is quite important, because recent exudations yield more readily to treatment. When it occurs as a well-defined tumor it should be differentiated from fibroid tumor, extra-uterine pregnancy, fibro-cystic tumor of the broad ligament, and hæmatoma. In all cases of doubt it will be safe to use electricity until the diagnosis is cleared up, for if it happen to be an exudation it will yield to the treatment, and there is no condition with which

it is likely to be confused that would be influenced unfavorably by its application. The electrical treatment of peri- and para- metritis is ordinarily confined to the subacute and chronic stage, or, in other words, to the exudation and the attendant congestion; for these cases are seldom seen by the specialist before an exudation has occurred and the acute attack has subsided. It is generally supposed that an active inflammatory state contra-indicates the use of electricity in any form, and for this reason it has been considered inappropriate in the treatment of the first stage; but Apostoli strongly advocates the use of the high-tension faradic current (that from fine-wire secondary coil) in the acute stage. He says, "The common feeling of the profession certainly is that a palliative treatment is all that can be adopted in this disease. When called to a woman suffering from perimetritis, or phlegmonous inflammation, it is mostly with reluctance and hesitation that anything more is done than to order soothing applications to the abdomen and to await results. I protest against this sterile inactivity, which prevents no mischief, does nothing in the way of cure, and leaves the disease to run its own way unopposed.

"Although the operative proceedings which I think necessary require great precaution, I undertake them for two definite objects: first, to calm down the pain the patient is enduring; and, secondly, to arrest, if possible, the inflammatory action, and to prevent its running on to suppuration. I faradize every woman, even when under an acute attack of inflammation, observing, however, the following practical rules:—

"(*a*) I proscribe every faradization that would cause the least pain, and expressly that of quantity, engendered by the bobbin with short and thick wire.

"(*b*) I use for such cases the bobbin with long and fine wire, from which I obtain a current of tension, on account of its specially anodyne effects.

"(*c*) I begin with a simple vaginal application by means of a bipolar electrode, the point of which is placed against the inflamed part.

"(*d*) I only employ a current easily bearable, so as to cause no suffering, nor any excitement of the patient, as this would insure an entire failure of the treatment.

"(*e*) All the success of this medication depends upon making the first sittings sedative, so that they may serve as a prelude to more active measures; and the faradization will only become hyposthenic on the double condition of its low intensity and its long duration.

"(*f*) Each sitting should last five, ten, fifteen, twenty, or twenty-five minutes, as may be required, and should not terminate before the patient spontaneously declares she is better and suffers less.

"(*g*) It is necessary to re-inforce what has been said by dogmatically averring that no success will come out of this treatment unless it be managed not only without violence, but with extreme gentleness.

"(*h*) There may be one or two sittings each day, as may be wanted, for lowering the febrile action, allaying pain, and bringing about what is called the subacute stage of the inflammation.

"(*j*) Every faradization should be preceded and followed by a vaginal irrigation with sublimate solution, and all the sounds should be scrupulously disinfected."

Of the *subacute stage* Apostoli says, "As soon as the sound can be introduced into the uterus without much pain and without danger I consider this stage to have set in, and it is necessary to make some alteration in the treatment." He advises the use of the faradic current of tension, by means of a bipolar intra-uterine electrode, to the uterine cavity, combined with an occasional galvanic application. The bipolar electrode must be introduced well into the cavity, so that the current does not take effect upon the cervical canal, which is very much more sensitive than the interior of the uterus. The current must be turned on very gradually, starting from nothing, and must be increased to a point of comfortable endurance by the patient. The application should continue, as in the vaginal method, from ten or fifteen to twenty minutes, and may be repeated every day or every second day, according to the indication. Galvanism of the endometrium must be in small and gradually-increasing doses, and the application at first should not be repeated oftener than once or twice a week, and the strength of the current should not exceed 10 to 30 milliampères (positive pole), used for three or five minutes. (It is better, in the beginning, to make the applications only three minutes.)

Apostoli does not employ the vaginal applications by means of the ball electrode, but I am satisfied that in many cases they give very much better results than when the current is applied to the endometrium, which is sometimes irritable. I believe that better results will be obtained by continuing the bipolar vaginal faradization and the vaginal galvanic applications with the ball electrode during the subacute stage, and until the chronic stage is well defined. An effective way of administering the current is to make the sittings every second day, giving a vaginal galvanic application of from 20 to 50 milliampères for five minutes, positive pole in the vagina, with a large electrode on the abdomen, following this application immediately by bipolar faradization of the vagina for five or ten minutes at each sitting. As to the position of the vaginal ball electrode, it is preferable to place it against the cervix as it presents to the touch, when the exudation is not localized, so that the current may traverse the whole structure of the uterus. As the case begins to show improvement, or merges into the chronic stage, galvanism of the endometrium may be substituted, using at first a strength of not more than 30 to 50 milliampères (positive) for three minutes, and not oftener than twice a week. In the interval between these galvanic applications, if a sedative effect is required, bipolar faradization of the

vagina may be resorted to. When a distinct exudation tumor exists, it will yield more promptly to the vaginal applications, with the electrode against the tumor in the vagina.

The rule to be followed is, if the tumor is sensitive, use the positive pole for five minutes, followed by bipolar faradization of the vagina, every second or third day until this sensitiveness is entirely overcome.

When the exudation is recent, rapid absorption will sometimes be influenced by the current applied in this way, and it will entirely disappear. If the mass is intimately connected with the uterus, and there is also a metritis and endometritis, it is advisable to make the applications to the uterine canal as early as the condition will permit, or as early as the uterus will tolerate the intra-uterine applications. When the exudation is chronic, complete absorption cannot always be produced by means of the positive pole, and it becomes necessary to use the negative pole, with a strength varying from 50 to 100 milliampères, the vaginal ball electrode being placed against the tumor and the external electrode either on the abdomen or lower spine, as is best suited for including the mass in a direct line between the two poles.

If the case does not progress favorably under this plan of treatment, the vaginal galvano-puncture becomes necessary; and it is best to use the positive puncture at first, because it provokes less irritation than the other pole, and frequently satisfactory and complete resolution may be effected by it; but when it fails of success, the negative galvano-puncture must be resorted to. The intensity of the current with the positive puncture may be from 30 to 50 milliampères, used for three or five minutes, and repeated not oftener than once in a week or ten days, or not until the reaction which follows has subsided. A platinum needle should be used. In the interval it is best to suspend all other treatment unless a sensitive condition calls for bipolar faradization. With the negative puncture, from 20 to 50 milliampères may be used for five or ten minutes. These punctures are to be made with a very fine needle, not larger than an ordinary exploring-needle, and the depth of the puncture should be only just sufficient to enter the mass, which will be from one-half to one centimetre.

The operation is done in the following manner, viz.: The vagina is first rendered aseptic (a douche of 1-per-cent. solution of creolin or lysol being used for this purpose), then the index finger of the right hand locates the tumor in the vagina at its most prominent point, selecting, preferably, the lateral fornix of the vagina, and taking care to avoid any pulsating vessel; the gutta-percha sheath or tube used for insulating the shaft of the needle is passed along the finger as a guide, pressed against the mass, and held in position by the free fingers and thumb of the right hand. The needle, which has been previously arranged so as to penetrate only the desired depth, is passed through this sheath until it touches the surface of the vagina, when, with firm pressure, it is made

to enter the mass at the point selected. Waiting until the temporary irritation of the puncture has subsided, the current is turned on very slowly until the maximum is reached; it is held there for a space of three minutes, and is gradually turned off, when the needle is withdrawn. The vagina is again douched with an antiseptic solution, and a loose tampon of iodoform, creolin, or aristol gauze is placed against the wound in the vagina. When necessary, this is renewed every twenty-four hours. For the first twenty-four or forty-eight hours it is advisable for the patient to remain as quiet as possible, when, if no undue irritation manifest itself, she may resume her usual duties; but her exercise must not be excessive, and she must be cautioned to recline, whenever she experiences any pain, until it subsides.

An anæsthetic is seldom necessary in making these punctures, as this procedure would not be indicated where much pain is produced by it. If it become necessary in a nervous, sensitive patient, the slight anæsthesia produced by a few whiffs of chloroform or ether, given only during the time of the application, will be quite sufficient. It is better, when possible, to insist upon absolute rest in the recumbent posture for an hour or two following these punctures; but they can be done at the office, and the patient allowed to rest in a sitting posture for the same length of time. Usually there will be no pain or inconvenience following the operation, when the condition is favorable for it. The positive puncture often affords much relief if the mass was previously sensitive. There is always more or less aching in the mass during the passage of the current, which is to be expected, as the local action is confined to so small a surface as the point of the needle; but apart from this there is usually no suffering. After the withdrawal of the current and the needle this usually subsides, and no other inconvenience is experienced.

Puncture is not advisable for recent exudations, but only for those which have become chronic. Recent exudations will ordinarily yield readily to positive galvanism by means of the ball electrode against the mass in the vagina. Puncture is also to be limited to localized deposits. Where the whole pelvis is involved in a mass of exudation which is general, vaginal applications with the ball electrode should be employed at first, and later, if it become necessary, intra-uterine applications may be resorted to.

What is expected to be attained by this plan of treatment may be briefly stated as follows: First, in the acute and subacute stages, relief of pain and a sedative effect upon the circulation are secured by the faradic current of tension; second, the galvanic current used in the beginning of the chronic stage, after active inflammation has subsided, lessens congestion and promotes absorption of recent lymph-deposit. Later, when this exudation has become a firm, solid mass, negative galvanism through the vagina hastens absorption and softens and relaxes adhesions. Galvanism of the endometrium relieves the inflamed condition of the uterine

body, as well as that of the lining membrane of the cavity. Puncture into the mass promotes disintegration and absorption *in toto*. A *restitutio ad integrum* is not always possible and should not be expected immediately from the treatment, but frequently the process of absorption is so stimulated that resolution continues after its cessation and eventually a complete cure takes place.

Resolution is the rule under this plan of treatment; at least, this has been my experience; and I have yet to see a single case where suppuration has taken place when it has been properly carried out. If suppuration occur, followed by the formation of an abscess, and fluctuation can be detected through the vagina, it would be useless to persist in the treatment; the pus must be evacuated. This may be done either by free incision through the vagina and the insertion of a drainage-tube, or by aspiration with the platinum cannula, and application of the current through this cannula afterward. It has been my experience that when aspiration has been performed in this manner no reformation of pus takes place. This method of aspiration has been described under the head of "Pyosalpinx," where the necessity for employing the positive pole after aspiration of pus-cavities is explained. Since cauterization of the track of the cannula is produced by the current, an opening, though small, is left for any subsequent drainage which may be necessary. This method is only applicable to small abscesses situated near the vaginal wall.

Attention is directed to the fact that the introduction of sounds and electrodes into the uterine cavity in these cases is to be done with great circumspection, and never unless every antiseptic precaution has been observed. For this reason it has been thought best to urge the treatment by means of the ball electrode in the vagina, when it will accomplish the purpose desired, in preference to intra-uterine applications.

Under this head may very properly be included adhesions resulting from inflammatory action involving the pelvic peritoneum, as well as contraction of the broad ligament, dragging the uterus out of position to one side of the pelvis. These conditions are to be dealt with by conjoined bipolar faradization of the vagina (current from fine-wire coil) and vagino-abdominal or lumbar galvanization. The positive pole is used in the vagina when necessary to allay pain or soothe an hyperæsthetic condition, but the negative pole is to be employed as early as possible for its softening and relaxing effect. A judicious application of massage following the use of the negative pole in the vagina will aid very effectually in bringing about the desired result. In lieu of this, much assistance will be rendered by a properly-arranged tamponade of the vagina, by means of elastic-wool tampons, which at first are saturated with a 10-per-cent. solution of ichthyol in glycerin.

Salvat[1] has recently contributed the following conclusions as the result of his experience with this agent in the treatment of parametric deposits :—

[1] Revue Internationale d'Électro-thérapie, vol. i, p. 122.

"1. In the cases of subacute and chronic parametritis the intra-uterine, positive, chemical, galvano-caustic applications combined with massage have produced rapid relief of the pain and active absorption of the exudate. After two or three *séances* the patients felt so much improved that they considered themselves well.

"2. The adhesions seemed to disappear much sooner than with massage employed alone.

"3. The leucorrhœa with which they were affected disappeared rapidly and they soon recovered their health."

PELVIC HÆMATOMA AND HÆMATOCELE.

Pelvic hæmatoma is an effusion of blood into the cellular tissue of the pelvis, beneath the peritoneum, and is usually located between the folds of the broad ligament; while pelvic hæmatocele is an effusion of blood into the peritoneal cavity of the pelvis. The latter is sometimes confined to Douglas's pouch, being closed in by adhesions, when it is known as retro-uterine hæmatocele.

Etiology.—A predisposition to these blood-effusions is induced by an impaired condition of the system, anæmia, plethora, too frequent child-bearing, and anything that causes an unusual fullness in the pelvic vessels. The exciting causes are referable to unusual exertions during menstruation, or following labor or abortion, strains, shocks, falls, or excessive sexual irritation. The vessels of the broad ligaments, especially where a varicose condition of the veins exists, are extremely liable to rupture during menstruation owing to their extreme fullness. Such varicosities are not unusual, and are more frequently the source of hæmorrhage than is generally supposed.

Diseases of the ovaries and tubes are frequently the cause of hæmatocele, the hæmorrhage resulting from rupture of a Graafian follicle, or of a vessel in the tube, and discharge into the peritoneal cavity through the free end of the tube. Ruptured tubal gestation is regarded by some authorities as a frequent cause of hæmatocele, but that every hæmorrhage into the cavity of the pelvic peritoneum is an evidence of a ruptured tubal pregnancy, as has been contended by some, is certainly an error.

Diagnosis.—The very sudden appearance of a tumor in a pelvis where none existed previously, coincident with a history of sudden, sharp pain and symptoms of shock and loss of blood, would certainly be pathognomonic. The differentiation would then be confined to an intra- or extra- peritoneal effusion. When the effusion is intra-peritoneal it is usually posterior to the uterus, is not at first distinctly outlined above, and usually there is not much displacement of the uterus, and, if so, it is forced forward. This would occur only when the blood is confined by adhesive bands, or is encapsulated. Inferiorly it bulges into the vagina as a smooth, tense mass, posterior to the cervix. If the effusion is extra-peritoneal, or within the folds of the broad ligament, the

resulting tumor is usually more defined, situated to one side of the uterus and displacing it laterally. Inferiorly it is uneven or nodular and may extend down into the recto-vaginal septum. In both conditions the mass is exquisitely sensitive to touch, extremely painful on account of the distension and forcible separation of adjacent structures, especially when the effusion is subperitoneal; and a metrorrhagia is induced by irritation of the uterus and interference with its circulation from the pressure of the mass. Blood-effusions are to be distinguished from inflammatory exudations by the fact that they occur suddenly, are traceable usually to an accident, occurring frequently during menstruation, and there is no history of previous illness, which would indicate an inflammatory attack.

The differentiation from fibroid tumors or ovarian cysts is based upon the sudden development of blood-effusions, their sensitiveness to pressure, and the fact that they are at first soft and elastic, then hard; whereas fibroids are insensitive and constantly firm, and ovarian cysts are less sensitive and fluctuating throughout. Finally, the exploring needle, which should be introduced under thorough antiseptic precautions, would extract blood or bloody serum if the mass is a blood-effusion; whereas nothing could be withdrawn if it was a fibroid. If there is any probability of its being a cyst, it would be wiser to allow time to establish a diagnosis than use an aspirating needle.

The enlargement of an extra-uterine or tubal pregnancy might be mistaken for a small hæmatoma of the broad ligament, but usually it is accompanied by the symptoms of pregnancy, and there is amenorrhœa, or a history of missed menstruation, instead of menorrhagia, which is frequently associated with blood-effusions. Its gradual development and increase in size within a short period, in the absence of anything to indicate a secondary effusion, would create a suspicion of tubal pregnancy which careful observation would convert into a certainty.

Treatment.—The treatment of these conditions is generally most unsatisfactory by the usual methods, not because of the ultimate result, for they most frequently end in recovery, but because of the slow progress. The treatment by electricity has been found to produce better and more satisfactory results than the usual methods by lessening the suffering of the patient and shortening very much the period of convalescence.

Abdominal section is never justifiable in these conditions where suppuration is absent, except when collapse is imminent from an uncontrollable hæmorrhage into the peritoneal cavity; and when suppuration occurs and fluctuation can be detected in the vagina, it is best to evacuate and drain by that channel, even if the effusion is intra-peritoneal, because if hæmatocele has reached that stage it is usually encysted and shut off from the general peritoneal cavity.

There are five chief indications to be met in the treatment of this accident, viz: 1. To check the hæmorrhage when the case is seen clearly enough. 2. To produce coagulation of the effused blood as quickly as

possible, and prevent a recurrence of the hæmorrhage. 3. To relieve the pain and prevent inflammatory complications. 4. To effect absorption and prevent the formation of abscess. 5. To shorten the confinement to bed as much as possible. We have in galvanism an agent particularly constituted for fulfilling these different indications. The positive pole relieves pain, lessens congestion, and favors coagulation, while the negative promotes absorption. It is only necessary to diagnose the indication correctly and apply the remedy accordingly.

To meet the first and second indications the positive pole is used, conjoined with absolute rest in the horizontal position, until all danger of a recurrence of the hæmorrhage has passed. Rest is essential, particularly in dealing with hæmatocele, where there is usually no limit to restrain the effusion. The positive pole meets these indications by promptly relieving the congestion and arresting the hæmorrhage by producing rapid coagulation not only of the effused blood, but also in the open ends of the ruptured blood-vessels.

This may be accomplished in two ways: first, by an application through the vagina with the carbon-ball clay-covered electrode, protected by a coating of egg-albumen to prevent cauterization, and a current long continued, commencing with 30 or 50 milliampères and gradually increasing until an intensity of 100 milliampères is reached at the first sitting. The electrode connected with the other pole should be so placed upon the abdomen or back as to include the mass directly between the two poles. This application should be repeated every day until the desired object has been accomplished. The second method of meeting these indications is by means of the positive vaginal galvano-puncture. The puncture is made with a very small needle into the mass as felt through the vagina, the preference of location being behind the cervix or to either side, and the direction in the axis of the pelvic brim to avoid the rectum. The depth of penetration need not exceed half a centimetre, and the strength of the current may be 50 milliampères used for five minutes. Strict asepsis is essential. One puncture will ordinarily produce coagulation of the effused blood, and further treatment can be carried out with the ball electrode in the vagina. When necessary, however, the puncture may be repeated, though it is best not to do so under two or three days, and a fresh location should always be selected. The galvano-puncture should be restricted to the treatment of hæmatoma, in this stage at least. These positive punctures should always be made with a platinum needle, and never with one which is corroded by the action of the positive pole. When done under thorough antiseptic precautions, there need be no apprehension of unpleasant consequences.

To meet the third indication, the relief of pain, the positive pole is likewise used. It acts by relieving the engorgement and hastening absorption by favoring osmosis of the fluid element and producing contraction of the clot, thus removing the excessive pressure upon the misplaced

organs. The relief afforded by the use of this pole in the vagina with the ball electrode and 50 milliampères of current is marked, but the positive galvano-puncture gives more relief. A tumor of this character, which was previously very sensitive to the touch, will be almost insensitive after a puncture, and considerable manipulation is necessary to provoke pain. The use of the positive pole combats the tendency to inflammatory complications and pus-formation. In hæmatoma suppuration should never occur under this plan of treatment if proper care is observed in the technique of the puncture, for a description of which the reader is referred to the section on "Pelvic Deposits."

To meet the fourth indication it may become necessary, in the stage of convalescence, to use the negative pole to hasten absorption, but usually absorption will go on rapidly under the use of the positive pole. This is especially true of the positive galvano-puncture, a small hæmatoma frequently being absorbed in a week or ten days after a puncture of 50 milliampères. The operation may be somewhat painful, but the relief following it is prompt. After puncture rest should be insisted upon until all local irritation has subsided. In the later stage it is better not to puncture oftener than once a week.

The negative pole should never be used until the clot is firm and all pain has subsided, or when its application is followed by pain. With this pole the vaginal applications only are employed. They may be made every second day with a current-strength of from 50 to 100 milliampères for five or ten minutes, and it is well to enjoin absolute rest for an hour or two after each application.

The suffering, which is ordinarily very acute in these cases, is rendered comparatively insignificant by this method of treatment, and the confinement to bed and the period of convalescence are greatly shortened. The general health improves steadily, instead of depreciating, as is usual in this class of cases after prolonged confinement to bed.

If suppuration should occur, the indication will be to evacuate and drain. Where feasible, this should be done through the vagina. The evacuation must be thorough, the entire contents of the sac being removed, the cavity washed out with peroxide of hydrogen, and a drainage-tube inserted. Perfect drainage must be maintained and repeated irrigation will usually be necessary.

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ENGORGEMENT AND DISPLACEMENTS OF THE UTERUS.

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Engorgement.

In days gone by it was the fashion to use vague and general terms to describe certain pathological complex conditions which are not constant in their somatic expression. Among these was the condition known as engorgement, where an increase of size of an organ without change in its substance was noticed. This was attributed to faulty circulation; but of the nature and origin of it nothing was known. Since then we have grown to be more clear in expression, albeit not always exact. Instead of preserving that which was really good in the old system, the entire system itself was discarded. It seems to me that in so doing the profession has thrown aside the term of "lesion," which is generic, the varieties of which have not been sufficiently well studied to admit of a strict nomenclature.

I shall continue to make use of the term "engorgement" in describing those lesions of nutrition which, if they be not pure hypertrophies or hyperplasiæ, are characterized by increase of size and weight of the organs affected. It shall be the duty of pathological histology to picture more fully the underlying conditions of anatomical change leading up to these changes, but, meanwhile, physiology can aid us substantially in our studies. In this way can we learn something of the manner in which exudates are absorbed,—these exudates being characteristic of these lesions of engorgement. And first let us examine what are the causes of these circulatory changes, and what is the mechanism of them. In every region and tissue the circulation has two great functions,—it arrives and it departs. In any circumscribed locality the blood that comes and goes is variable in quantity and in the rapidity with which it flows. When these relations are normal, a just equilibrium follows; but if, for any cause whatever, a disturbance of the harmony of these relations takes place, the mechanical conditions are disturbed. This disturbance will be best understood by considering what are the prime factors in the make-up of a lesion. Claude Bernard has shown that there was excessive circulatory activity in the region of paralyzed nerves. Just the reverse happens in nerve-stimulation,—the activity of the circulation is checked. Now, here are two types of functional elementary anomalies which might exist for some time without becoming abnormal or engendering morbid change. The first is a type of local hyperæmia, the second of local

anæmia. It does not necessarily follow that there is any disturbance of equilibrium between the afferent and efferent supply, and no pathological state will occur while the equilibrium is preserved. Should the arterial supply be excessive, or even normal, while the venous supply is diminished, the region thus acted upon will retain too much blood. Should the arterial supply remain normal, or become lessened, and the venous return be sufficient to prevent congestion, but not sufficiently active to take care of the supply that arrives by the arterioles, a condition of stasis will result. Congestion and stagnation, or stasis, are the absolute or relative consequences of venous change. These are pathological states. What do we know clinically of these? For thirty years or more congestions have been improperly called hyperæmiæ; and "stagnation" has been replaced by many new names. When there is a slight mechanical disturbance to the arterial flow supplying delicate organs (brain, heart, lung, kidney, etc.) congestion is only a transitory phenomenon. In addition to these instances there are others which pass into different stages of *resolution* and *inflammation* in the absence of therapeutical interference. *Stagnation* may ensue when inflammation does not set in, and resolution comes on slowly. Simple congestion is due to causes which are independent of immediate local disturbance. Its condition varies with age. In the uterus—more than in any other organ, perhaps—are the changes in the series of nutrition, from recent congestion to chronic stagnation, very frequently made out. These abnormal conditions merge themselves, the one into the other; not capriciously, but in a regular, well-defined way. *A priori*, two methods seem to determine the relief of a congested region. The one consists in a periodic return, at short intervals, of anæmia; the other in the provocation of transitory hyperæmiæ. Just here I shall point out the treatment of congestions by producing a local anæmia; not because I can recommend it, but because it supplements and aids the physiological effort. Leeches relieve congestions, but only for the moment; they re-appear, possibly, as phlegmasiæ, to which bleeding predisposes. The best that we can hope for in local bleeding—and I do not believe that it has ever accomplished this—is to hasten the period when the congestion would pass into stagnation. Continued voltaic shocks, especially in some regions, seem to give the best results. If I cannot recommend the treatment of congestions or stagnations by the production of local anæmia, I am quite willing to admit that such a course, intelligently worked out, may be a remedy for recent conditions of engorgement. I should prefer to treat engorgements, especially such as are chronic, by the other method, namely, by the repeated production of passing hyperæmia. Once, having treated with faradization a hydrocele with an encysted cord, I found that the pulsations of the spermatic artery, which, in a healthy condition, it is impossible to make out, became very apparent during treatment, and remained so during the *séance*, but immediately ceased to be perceptible

when the sitting was ended. Therefore, faradization caused a decided hyperæmia of the mass, limited exactly to the time during which the induction current was active. Why should not this plan of forced hyperæmia be useful as a means of drainage for the relief of chronic disturbances of circulation, perhaps of recent ones as well? Reasoning in this way, I commenced the treatment of these states of engorgement by faradization, localizing the current in the part suffering. Currents from the coarse-wire bobbin, with from 15 to 30 interruptions per second, were used, for periods of time ranging from three to ten minutes.

Prior to 1861 it was my habit to use the extra currents from the apparatus devised by Duchenne. In order to facilitate the graduation of intensities I replaced Duchenne's apparatus with the induced currents furnished by the apparatus here figured (Fig. 1). I first used this method in 1859, in the treatment of engorgements of the uterus and prostate. In the uterus I use a cervical electrode, the other electrode being over the abdominal or lumbar region. On account of the relatively obtuse sensibility of the uterus the negative rheophore should be attached to the intra-cervical electrode. At first there should be daily sittings of five minutes. As soon as the uterus reacts the sitting should continue only three minutes. Starting from an almost imperceptible point, the strength of the current should be increased gradually and with reference to the patient's tolerance. If after the *séance* the patient walks easily and confesses that she is free from the pain that tormented her previously, we may know that the strength of the current was properly graded. If there should be no complications, or no general condition contra-indicating the use of the current, amelioration occurs after three or four sittings. The very moderate amount of pain experienced in the region of the external electrode may be reduced to *nil* by making this of large surface and keeping it moist. After a time pains in the uterus simulating labor-pains are felt. This does not always occur during the first sitting, even after a sitting of five minutes.

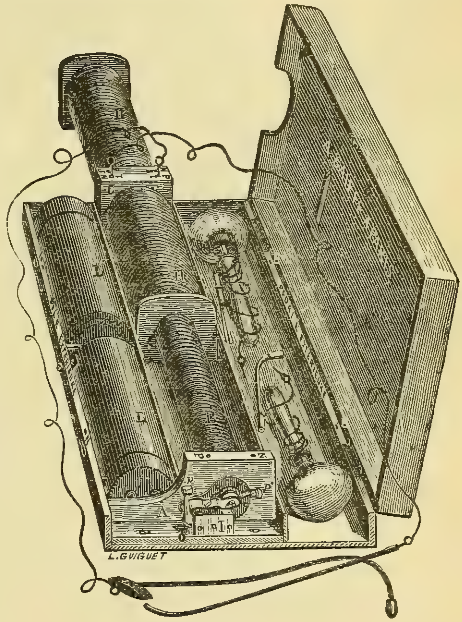

FIG. 1.

Formerly I used the bipolar intra-uterine method, but I was not

satisfied with it. The difference in intensity resulting from the accidental but inevitable unsteadiness of the contacts was more unpleasant to the patient than the method which I now use. The bipolar method has been taken up by Apostoli, who seems satisfied with his modification of my electrode. I have not, however, found any more satisfaction in using it than I did in using my own electrode with cervical rings.

This method of treatment for circulating derangements by hyperæmic drainage allows of many applications. In dysmenorrhœa, as well as in the pains of post-partum congestion, this method is useful; also, as a derivative, in the pulmonary congestions of the menopause.

Displacements of the Uterus.

When lesions of position and form in the uterus are not caused by a tumor, they are generally known as displacements; this generic term is given to flexions as well as to versions, or falling. In speaking of lesions unconnected with a tumor, I do not mean independent of a lesion of nutrition. There are simple lesions of nutrition; these are caused by some mechanical trouble of the nutritive process in the physiological vicissitudes of that organ. We find them in almost all, if not in all, simple lesions of nutrition, as well as in all affections where defects of position or form are to be met with. I refer to the term "engorgement" for all that relates to the genesis as well as for the general treatment of simple lesions of nutrition.

In pathological phenomena engorgement plays a considerable part, I might even say a predominant one, where the subjects apertaining to displacements or malformations are concerned; moreover, it receives the same treatment which I give to displacements or malformations. A soft and unsettled organ, subjected from all sides to accidental pressure, is necessarily exposed to displacements and malformations, and it is sufficient to name these to have them defined.

At first sight these fallings, versions, and flexions form purely physical lesions, and a mechanical treatment would be justifiable. These indications have always been understood in this way, and mechanical means have generally tried to fulfill them; but experience has condemned these practices, and I shall not dwell on their examination; however, an exception should be made in favor of the hysterophore of Grandcotter, for cases of fallings, the supports being external to the pelvis, and the soft pressure graduating of itself. The vascular richness of the uterus and the circulatory vicissitudes that occasion its functional life easily create a semipathological state, while at the same time predisposing it to influences that tend to alter its position or form. This is explained under the head of "Engorgement."

Just now this character seems to me a prevailing one, and the mechanical treatment it receives only tends to aggravate the trouble.

Fig. 2 represents the normal position of the uterus; it is taken

from the congealed body of a young girl of 19. It explains itself. The other displacements are defined by the directions taken from the bottom of the uterus; when it falls forward it is an *anteversion;* when it falls backward, a *retroversion;* and when it is inclined to one side, a *latero-version.* When I discovered, in faradization of the mass, a means of exciting circulation and stirring a languid nutrition, I had also to take into consideration muscular contraction independently of its action on the circulation. Muscular contraction in muscular organs, consequently in

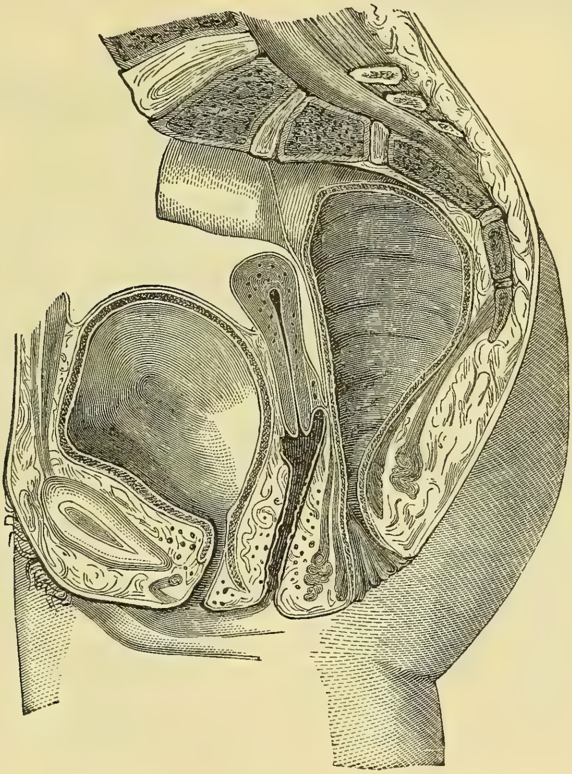

FIG. 2.

the uterus, cannot go on without being localized or without constituting an orthopædic condition. Faradization for prolapsus was used simply to form an adjuvant to the mechanical means of support.

The muscular fibres in the attachment of the uterus are not sufficiently abundant to hope that, in these relaxed conditions, they could be shortened by acting on them. Little benefit can be derived, and this only according to the diminution of the weight of the organ, obtained after the engorgement has ceased. However, notwithstanding the slight effect of faradization, embracing the ligaments in its circuit, it would be well to

note this as far as possible. When I come to the operative process, farther on, I will show how this can be secured. There is more to be expected from versions and flexions. It seems clear that if contractions can be localized in one of the walls (I will point out how this can be accomplished) a shortening and shrinking of the part will take place, and can be made available to straighten the organ. At first, of course, this

FIG. 3.

shortening will only be temporary, but by repeating it with perseverance, part of it, at least, will be lasting.

In fact, for thirty years or more, experience has proved to me that the uterus, simply congested and deviated or bent, can in time recover its normal condition, provided it is free from pathological adherences, though it might take a long time to reach this end. Faradization of the uterus is made by applying induced currents by means of an exciter introduced

FIG. 4.

in its cavity, or simply in the cervical canal, the circuit being closed on the exterior part of the organ, either by the rectum or bladder.

The *rectal* exciter (Fig. 3) consists of a metallic olive-shaped point on an insulated handle, the bend of which should be about the same as that of the concavity of the sacrum.

The *vesical* exciter (Fig. 4) is a female catheter covered with an insulated coating to within two and one-half centimetres of the end.

FIG. 5.

The metallic part, having a slight bend given to it, should rest on the wall of the posterior part of the bladder.

The *uterine* exciter (Fig. 5) consists of a large probe, also insulated. It is well to have at least two of these,—one straight and the other bent at the end. The first is the easier for application in cases of retroversion, the second in cases of anteversions. When the current is obliged to be

closed exteriorly, I use large knobs of charcoal covered with chamois-skin or pieces of sponge, on which should be applied a leaf of tin-foil. Of course, the larger these abdominal exciters are, the less will be the pain resulting from the application. This is most important to remember, as a great many doctors have considered uterine faradization a most painful operation, and the reason is a very simple one, namely, that they close the circuit on the abdomen, using exciters with small surfaces.

The abdomino-uterine, sacro-uterine, and lumbo-uterine faradization processes, tending to produce contractions of the mass of the uterus,

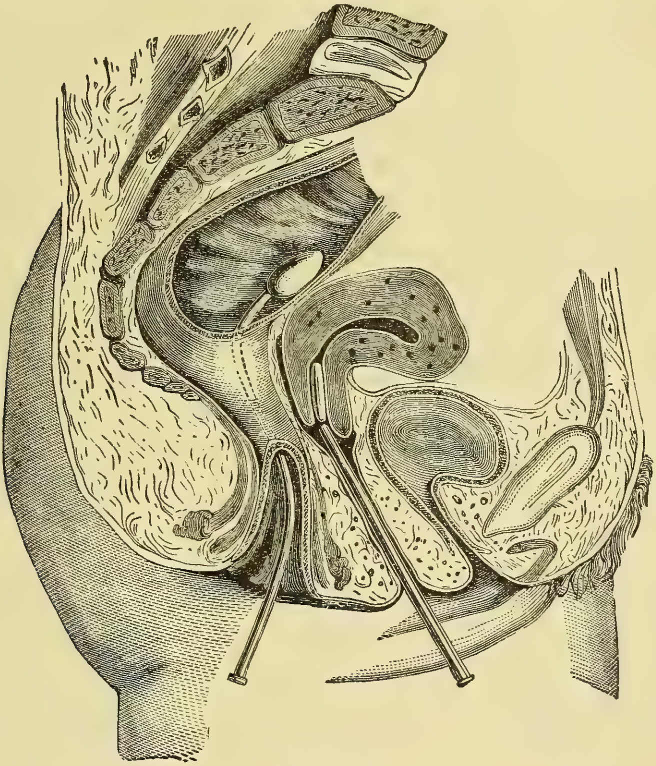

FIG. 6.

without influencing the adnexæ, have been described under the head of "Engorgement."

The posterior part of the uterus must be acted upon for anteversions and anteflexions when treated by recto-uterine faradization. The patient must lie down as for an examination with the speculum. The seat projecting a little from the arm-chair, the uterine exciter is first introduced, then the rectal exciter. The uterine exciter should then be attached to the negative rheophore, the rectal to the positive. During the sitting the rectal exciter should be moved slowly from side to side in order that it shall rest more and more on the posterior part of the uterus (*vide* Fig. 6).

Formerly, I embraced at the same time the entire hypogastric region; I have since given this up, the manœuvre only presenting small advantages as opposed to some real disadvantages.

The first thing to be done is to grease the rectal probe, although it is the last one used, as later the operator would have no disengaged hand to do so. Then a towel should be placed within reach.

The uterine exciter, having been dried by the left hand, is introduced, using for this purpose the left forefinger as a conductor. After this the rectal exciter is introduced; this is the most delicate part of the operation; if not well done it might be very painful. The olive must pass the internal sphincter, leaning a little on its upper edge, the concavity of the instrument pointing downward; after this it should be pushed forward, below, and a little to the left. When the olive has thus reached the bottom of the concavity of the sacrum a pause should ensue, then turn the probe while elevating its pavilion so that the concavity of the curvature is turned upward, and in this way cause the olive to face the back wall of the uterus. It would naturally seem that, on account of the development to the left of the rectal ampulla, the rotation would be easier on that side, but this is not the case; I have always found it infinitely easier to the right, and I have tried it both sides. After pushing the olive from right to left in the concavity of the sacrum, it must be brought back to the right, while turning the concavity of the probe more and more toward the right. The pavilion, being held in the hand of the rectal probe, must be slowly elevated during this rotation movement until it has been completely effected. This precaution is necessary, first, in order not to use the uterus roughly; then, that the movement of rotation may be more freely effected.

When the curvature of the probe has been brought parallel to that of the sacrum, then only can the hand be gently lowered, pushing lightly so that the olive may come up sliding against the wall of the uterus.

This last motion, however, must only be accentuated when faradization has begun, in order to give it strength and assure a sufficient contact. The rotation movement just described is not always accomplished without meeting with some resistance; this is sometimes easily overcome, but at other times it may be more difficult. The operator should be able to judge according to the impression received by the hand controlling the probe. The most ordinary obstacle to this manœuvre is the presence of a fæcal mass, hard or soft, and it is something that cannot be foreseen. The best way to diminish it is to give the patient an injection of oil before the sitting.

The rectal exciter, once placed, should be held in position; then the rheophore must be attached with the right hand, which must at the same time hold the uterine exciter. It is necessary to get accustomed to manage these two exciters with the same hand, the other hand being free to control the faradic battery and to govern its action. The hand directing

the apparatus must, however, be able now and then to assist the other one, if any cause should present itself to modify the connection of the two probes, in accentuating the motion of the rectal probe. The fact is that a definite position cannot always be given at once to the rectal probe. I have already described one obstacle to its progress,—the existence of a fæcal mass in the intestine. If this should happen to be of any considerable size and a little soft, it might cover the posterior wall of the uterus as with a plaster, which could only be penetrated little by little during the operation. Muscular contractions form another obstacle to placing of the probe. These alter the form of the cavity where the evolutions take place. They are of a flexible nature, and give way under the influence of faradization; however, the resistance they present cannot be overcome at once, and it is by interrupting the rotation during the operation that this can be completed. Here I must say a word of the pain caused by uterine faradization. There is certainly a disagreeable feeling attending this process; for instance, certain tinglings, cramps, and movements of the limbs, caused by the sudden excitement of the sciatic nerves. They are inevitable when the rectal ampulla contains excrement; they form a circuit of derivatives, which carry more or less of the currents to the sacral nerves.

If I have dwelt so long on the manual of recto-uterine faradization it is because its accuracy is so important, and because no other process can take its place in those cases for which it is recommended.

The anterior part of the uterus must be acted upon in cases of retroversion and retroflexion, and vesico-uterine faradization must be employed. The patient must lie down as for an examination with the speculum; the uterine negative exciter is first introduced, then the positive vesical, which is previously greased. After this the contacts are established and the apparatus put in action; the same hand then places the two probes in the required contact. The introduction of the vesical exciter is made like that of any ordinary probe; the pavilion must be raised at the time of operating, but only at that time, so as to lean the disengaged end on the anterior part of the uterus. When there is a complication of deviations toward the front or back, as well as lateral deviation, the rectal or vesical exciter should be supported on the left edge if for a right latero-version, and on the right if for a left latero-version (*vide* Fig. 7).

For decided falling of the uterus faradization alone can never effect a cure; however, it can be of great help. The symptoms that must be fulfilled are: to reduce the weight of the uterus and cause its attachments, as well as the muscular fasciculus of the vagina, to return to their natural condition. In order to fulfill the first of these,—that of reducing the weight of the uterus,—it would be best to choose, among the processes given under the head of "Engorgement," whichever is best adapted to each particular case. If we are not so well prepared to treat the other thoroughly, still we are not completely at a loss; when the tumor is or has

become reducible, two processes can be used with advantage,—one by operating on the round ligaments, the other by using the walls of the vagina. The first is "bi-inguino-uterine" faradization, for which, once the negative uterine exciter is in its place, two moist plugs are applied on each side of the os pubis, where the round ligaments expand at their egress from the inguinal canal. The second is "bi-inguino-vaginal" faradization; the two positive knobs are applied on a level with the aperture

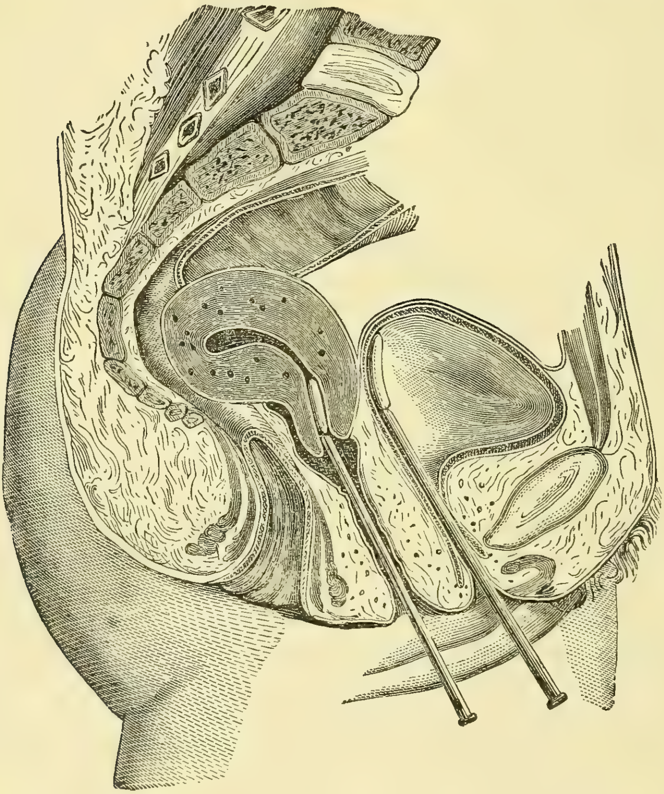

FIG. 7

of the inguinal canal together, the negative rheophore being attached to a large speculum placed in the vagina.

The pains caused by faradization of the uterus are of two and even three kinds. At first the patient feels a tingling sensation; this is caused by general sensitiveness. After a time that varies according to the degree of inertia of the organ, contraction pains manifest themselves; these are quite different from the first.

Between the two pains movements of the womb are often observed; these sensations are generally due to contractions of the lining membrane; some patients compare them to the working of a mill, others to shocks

imparted from the movement of the fœtus during gestation. Women who have been confined generally compare these uterine contraction pains to the first pains of parturition. Those who have had no children do not know to what to compare them, as they are not exactly like uterine pains from which they suffer before and toward the end of the menses. All women compare them to cramps, or to a transversal "bar" on a level with the os pubis. These uterine contraction pains are of a kind which are very soon forgotten; they cease immediately after the sitting, a feeling of relief is felt at once, and they leave no dread of the next sitting. This feeling of relief is described by all patients with the same formula, "I feel lighter; I walk better."

It may happen, especially at the beginning of a treatment, that the patient feels perfectly well after the sitting, and then pains will come on during the night; these are more or less like contraction pains. I consider them the effect of the sitting, the action prolonging itself insensibly until a time of rest, when the increase of the reflex power would make contractions more appreciable.

Although a diagnosis of metritis (which I only admit under reserve) has rarely stopped me, I have never observed consecutive pains which could be attributed to faradization, or, in fact, anything like an inflammatory process. However, I will say that if I believed more fully in metritis I should find reasons to abstain from faradization. There are generally two counter-indications to the use of faradization; the first is fever, the second a tendency to suppuration that is most necessary to avoid.

When I began this method of treating engorgements and displacements of the uterus I had the sittings last for ten minutes; this was too much; contractions must be obtained, but the muscles should not be fatigued. After feeling my way, I have decided to have the sittings last for three minutes, counting these either from the beginning of faradization or from the contractions, according to the degree of inertia of the organ.

Contractions are never discerned at the beginning of faradization. The intensity of the current must be slowly and continuously increased until they appear, but when they once manifest themselves the intensity should only be augmented from time to time, simply to keep up the energy, without trying to extend it in any appreciative way. Contractions are more difficult to obtain when the engorgement is old and considerable. I have had to wait for them sometimes five minutes or even more at a first sitting, but at the next sitting they appear more quickly. Now, at what period in the month is this treatment employed most usefully? The uterus has generally seemed to me more sluggish when the time for the menses approaches; this is no reason to abstain from the treatment. It is more sensitive during the menses, but not more easily contracted for this reason. Immediately after the menses the uterus may have more or less contractibility, and may be either ordinarily sensitive or more so than

usual, but rarely less so. I am in favor of daily sittings for the first month; the following months they can be less frequent.

If the case should prove to be a version without flexion, I consider three sittings a week sufficient for the second month, and two each week during the third month. After this I should stop, unless some complication prove the necessity of continuing the treatment.

The treatment must be a longer one when the case is a flexion, but the sittings need not be so frequent. The rehabilitation of the uterine tissue on a level with the flexed part forms the condition on which the cure depends. Now, this rehabilitation cannot take place rapidly; it requires all the more time when the break is complete. For this case it is useless to try and hasten the straightening, and occasional sittings will make a satisfactory treatment if continued for a long time.

It has often been said that pregnancy will cure a deviation. This is merely a popular opinion,—a prejudice which can be accounted for by a certain theoretical probability more than by facts. After confinement the uterus presents favorable conditions for retracting its form, and it is my opinion that this begins as soon as possible,—that is, immediately afterward. This practice offers, as far as displacements are concerned, many resources, besides other advantages of a more general nature. They will be found described in the article on "Obstetrics."

During the febrile crisis general sensitiveness to faradization is very much increased, and forms a counter-indication which I consider absolute. I require any women who come to me with pessaries or hypogastric belts to take them off at once; however, I except from this proscription hysterophores. If, after the first sitting, the absence of the bandage is a privation to them, this feeling disappears entirely after three or four sittings, at intervals of twenty-four hours. I prefer, for repose, a horizontal position to that of a sitting posture; however, this is not a condition essential to the treatment; on the contrary, I advise my patients to walk immediately after the sitting. The benefit they derive from the exercise is a last acquisition, and the fatigue will soon pass away; however, should this last be too great, the inconvenience felt would disappear at the next sitting. What I have just said of exercise in general can be applied as well to sexual function.

The most ordinary complications of displacements and deformations of the uterus, but especially of engorgements, are uterine catarrh and dysmenorrhœa. The electric treatment is the best for dysmenorrhœa. A similar treatment can be used for uterine catarrh. We shall not stop to examine it now, but I will give an example here. The increase of leucorrhœa, or mucus, after the first sitting. It would be wrong to imagine this proves an increase of morbid secretions; the fact explains itself by the greater facility of the excretion. An obstructed uterus, more or less sluggish, empties itself badly; a bent uterus still more so. Under the influence of contractions it ejects its contents, and this can be repeated to

such a degree that the increase of the catarrh can be easily imagined; but after a few sittings, when the organ gets more settled, the flow will diminish suddenly and remarkably, even when no special means have been used to stop it.

Any adherences holding the uterus in a bad position make the prognosis of deviations less favorable; this is a most ordinary occurrence. If deviations persist after three or four months' treatment, indicating some obstacle of this kind, I do not go on with the treatment, and content myself with the relief obtained, which is often to the patient equivalent to a cure. When the engorgement has disappeared, menstruation regulated, catarrhal complications removed, and the general state satisfactory, the deviation will only be recognizable to the touch, and will cease to annoy or need any more treatment. However, I should recommend my patients, leaving me in this state, to return and submit to two sittings of faradization each month for some time to come. Most patients neglect this, and only a few return once a year, or even every two or three years, having lost very little, but who come, on account of a slight leucorrhœa or heaviness of the pelvis, to ask for a little touching up; this is done in two or three sittings.

When I began these trials I admitted, with others, that when a gravid uterus received faradization a miscarriage was brought on; this is not so, however, as can be verified in the article where obstetric contingencies are treated.

DISORDERS OF MENSTRUATION.

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Introductory Remarks.

In commencing the part of this work devoted to the disorders of menstruation and their treatment by electricity, I cannot refrain from expressing the wish that the duty had devolved upon some one abler than I. For, in a work on electro-therapeutics, one might expect to find that all the diseases mentioned therein should be treated by electricity, and electricity alone. If that were expected of me, I feel that I am not one of the best qualified to fulfill the task, for my position as a professor of gynæcology, as well as that of a hospital surgeon, naturally compels me to teach and to put in practice not only electro-therapeutical, but every other means of cure—sometimes many of them at the same time—which will in any way conduce to the improvement of my patients. Then again, many of the cases which I am sure would be benefited and even cured by this means alone, if I had the time to devote to them which they require, I am obliged to treat by surgical procedure for want of time and from the difficulty of obtaining assistants who could relieve me of the duty of carrying out the electrical treatment which I would prescribe.

When I visited Apostoli's clinic I was so convinced of his honesty of purpose and of his ability to judge of the value of electro-therapeutics in gynæcology that I adopted his method more or less in my hospital and private practice; but it cannot be expected that one who has to spread his attention over a great variety of therapeutic and operative measures will obtain the same skill as one who wields but the one weapon, and who, consequently, becomes exceedingly proficient in its use. This, to my mind, is a sufficient explanation why none of the followers of Apostoli have ever obtained such good results as they have seen obtained by him. His experience in cases of menorrhagia alone is probably greater than that of any other man living or who has ever lived. His skill in handling electrical apparatus—especially the ones he uses most (the continuous or galvanic and the interrupted or faradic current) —is also much greater, for the simple reason that he is using them daily and for many hours a day. For the above reasons I have not a very large number of cases to report showing the benefit of this treatment, but in the majority of those whom I have so treated the result has been exceedingly gratifying.

I will not deny that the care of the battery and electrodes makes a serious inroad upon the few short hours which the busy man has at his

disposal; and I fancy that this reason alone has made the electro-therapeutic treatment of diseases of women exceedingly unpopular with those who, having a more or less extensive experience with surgical operations, have become dulled, so to speak, to the seriousness of the responsibility which they undertake in performing abdominal sections. Abdominal section, with removal of a bleeding fibroid, for instance, will only require a half an hour of the surgeon's time—an anxious half-hour it may be; but, then, it is over soon, and the patient is then handed over to the care of nurses, who relieve the operator of most of the remaining anxiety attendant upon recovery. The bleeding has been stopped with absolute certainty there and then, and, if the patient recover, the surgeon wins not only great *éclat*, but a handsome fee. With the electro-therapeutic treatment of such a patient, while the result of stopping the hæmorrhage will eventually surely be the same, the road to reach it is a much longer one and beset with many difficulties, the greatest of all, however, being the large number of applications which are sometimes required and the considerable time occupied by each application. By one who is doing nothing else at his office or his clinic but using electricity, a large number of cases can be treated in a day; for the patients may be prepared by the nurse, and rapidly replace each other on the operating-table, so that as many as five or six an hour may pass through his hands; but when this is only one of many different methods of treatment, the time occupied by one or two cases is proportionately very much greater.

The battery must be tested, and, if found wanting, the fault must be discovered and repaired. This alone is sometimes a most difficult task, involving the loss of an hour or more of time, as any one of the 240 items which go to make up a battery of 60 cells may be at fault. The carbon, or zinc, or jar may be broken, or the liquid muriate of ammonia may be exhausted. Then, the instruments and the patient must be disinfected, the abdominal electrode warmed, the connection made, the galvanometer adjusted, and the current turned on; and, after all that has been done, clear five to ten minutes are required for the passage of the current; so that one must be a firm believer in its superiority over other measures of treatment in order to be a staunch adherent of this method.

The difficulty of learning enough about electricity to employ it I consider a small part of the possible objections, for there is very little knowledge required. In cities and towns where the services of a young electrician may be obtained, he might certainly relieve the practitioner of a great deal of the trouble necessitated for the care of a battery; but, where one has the time to care for a battery himself, all there is to be done is to keep it full of water until the solution of muriate of ammonia is exhausted of its muriatic acid, when it must be thrown out, the jars, zincs, and carbons cleansed in hot water, and a fresh solution made, filtered, and introduced. With the Law telephone-cell the trouble of

keeping the battery in order is reduced to a minimum; for a battery of 60 cells will work sometimes for six months without even being touched, if kept well sealed and in a cool place. With open jars the evaporation takes place much more rapidly, and, consequently, the solution becomes so strong as to deposit crystals, and the battery is soon destroyed, requiring a thorough overhauling every month or two.

A very essential requirement for the successful employment of electro-therapeutics in disorders of menstruation is to accurately diagnose the condition present,—and, unfortunately, gynæcological knowledge cannot be obtained as easily as the battery can be purchased. This has been one of the greatest misfortunes with which this excellent method of treatment has had to contend,—that those, as a rule, who are most experienced, and who would, therefore, be most likely to employ it in appropriate cases, which have been carefully diagnosed, have condemned it without trial; while those who have been ready and willing to give it a fair trial have very often had little or no gynæcological experience. I see this on looking back over my own experience with it, and recall the failures I have had with it; I can truly say, in the light of larger experience, that all the failures have been clearly due to errors of diagnosis not only made by myself, but by others with whom I consulted.

When this method of treatment has been employed for a reasonable length of time, by men of large experience in diagnosing pelvic diseases, the result, on the whole, has been eminently satisfactory. Apostoli, himself, is a very experienced diagnostician, as has been testified to by all those who have watched him at his work. Keith, of London, who has a world-wide reputation as a gynæcologist and abdominal surgeon, has also been remarkably successful with this treatment, and never loses an opportunity of stating his satisfaction with it. Mundé, of New York, who, as a pioneer, used it largely long before it had come into fashion as it has at present, found it exceedingly beneficial to the majority of cases; and so on, through a long list of leading gynæcologists of nearly every country on the globe.

To me it seems simply impossible—quite apart from my own satisfactory experience with it—that so many able men of every land could be so deceived, as they must necessarily be, to all agree that this is a valuable means of treatment if it were not so. Even supposing, by some magical influence, that they had been misled by what they had seen at Apostoli's clinic (as has been suggested by Apostoli's greatest surgical rival), they would, at least, have soon discovered the fallacy of his pretensions when they reached their homes and put his method into practical application. On the contrary, we find them a year or two afterward reporting, sometimes, hundreds of cases which have been benefited by this treatment.

What is still more convincing is that there are many who are using it now with the most gratifying results who have never even seen Apos-

toli nor been taught by any of those who have seen him. They have picked it up themselves from a perusal of his writings. Among such I might include Martin, of Chicago, who has been almost as successful with this treatment as the master himself. Then, again, during the eight or ten years since its introduction on an exact basis by Apostoli, how many remedies have been introduced, highly vaunted, largely sold, fairly tried, and failed and disappeared? I might only mention, for instance, the sulphuretted hydrogen-gas treatment for consumption. On the contrary, a remedy which, like electricity, has been employed by thousands of picked men, and found sufficiently satisfactory by the most of them to be preserved among their resources, must surely have some inherent virtues which we have no right to value lightly.

In spite of the great number of very able men who are daily employing and testifying to the good results of electricity in disorders of menstruation,—or, rather, in diseases of the uterus and appendages which lead to disorders of menstruation,—electricity still finds many and bitter opponents in those, and in those only, who have but one other alternative to offer, and that the extirpation of the appendages, with or without the removal of the uterus.

In America especially, probably owing to the enterprising spirit of its people, the aggressive school of surgeons has progressed rather too rapidly in the wrong direction. According to them, amenorrhœa should be treated by the removal of the ovaries, because they are not working, and are, therefore, of no use; scanty menstruation should be treated in the same way, because they are working badly. In dysmenorrhœa they say, "Why allow menstruation to go on when it causes pain? Remove the appendages and bring on the menopause." In menorrhagia the uterine function is causing too great a drain on the vital fluid; the quickest way to put a stop to it is to open the abdomen and extirpate the offending organs. In metrorrhagia, even, there are, no doubt, some enthusiasts who would consider it a waste of time to inquire into the cause of the bleeding, although on this point I am not quite sure; while, for the menopause, no one, so far as I know, has yet proposed to remove the appendages, although the principle *similia similibus curantur* may yet be invoked by homœopathic laparotomists. It never occurs to these enthusiastic operators to try the effects of approved local and general treatment. For those who conscientiously do so, and in the majority of cases cure their patients, they have such epithets as "nob on a log who followed the do-nothing policy."

In a recent paper by Dr. C. Henry Leonard, of Detroit, in the *Illustrated Medical Journal* for January, 1892, the author has cited the opinions of some leading authorities who adopt the conservative view of the treatment of these diseases. For instance, Dr. Robert Bell, in a paper read before the British Gynæcological Society, said: "The radical operation should not be thought of until medical treatment over a

prolonged period has been thoroughly carried out and so proven unavailing." He felt that by far the larger number of cases could be cured by the more benign influence of medicine and its appliances. He stated that he had treated over two hundred cases of diseases of the appendages during the past year, and had found it necessary to operate upon but seven. He was convinced that a great many women are now going about without ovaries who might still be in possession of them and yet be restored to a healthy condition. He regarded diseases of the tubes as secondary effects of uterine diseases, and that to effectually combat a tube disease you must first cure its cause found in the uterus.

Dr. W. J. Corcoran is also cited, in a paper read before the Brooklyn Gynæcological Society upon "Pyosalpinx." Many cases are recorded of undoubted pyosalpinx, as proved by the expression of pus from the tube through the uterus into the vagina, where extirpation was not practiced, either through the conservatism of the surgeon or the absolute refusal of the patient, which, nevertheless, went on to more or less complete recovery. He also points out the fact that a great many women who figure in statistical tables as recoveries, as against deaths, absolutely refuse to regard themselves as cured, but, on the contrary, even claim to be worse.

In discussing this paper, Dr. Skene, the veteran Professor of Gynæcology in the Long Island College School, reported a case of hydrosalpinx in his practice that recovered without the use of the knife, and has remained well for years. He stated that he had seen others who had recovered in the same way. He mentioned another case of a patient in the hospital who, after consultation, had been condemned to operation, but who, on being examined on the operating-table, was found to have improved so much by the preparatory treatment that no operation was performed, and the patient recovered.

Dr. Burns, who surely ought to know of what he speaks, for he is the President of the American Gynæcological Society, the most authoritative body of men on this specialty in the world, said that, on looking back thirty or forty years, he could recall a great many cases where complete recovery has followed treatment other than surgical, and with complete restoration to health. He added that he could not recall a single case in which death had been due to rupture of the tubes; and although he testified to the wonders worked by abdominal surgery, he could not but think that laparotomy is abused and women often unsexed without warrant.

Dr. A. W. Johnson, of Cincinnati, is also quoted by Dr. Leonard as having said, in a paper read before the Union District Medical Society of Indiana, that in no place in the whole of our healing art does patience and care and intelligent treatment accomplish so much as in the management of chronic diseases of an ovarian tube; and he stated that his own teacher, Mr. Lawson Tait, had said: "Other chronic inflammations will

get well; why not this, when properly looked after?" Although Mr. Lawson Tait is one of the most bitter opponents of electricity, he is not such a rabid laparotomist as he is thought to be, as will be seen by the following note of 90 patients treated at his clinic: Of these, 15 had diseased appendages. Out of the 15, only 1 was selected for immediate operation, she having, as it was found, about three ounces of pus in one tube. Dr. Johnson watched these cases for four months afterward, by the end of which time only 2 more had been operated upon, 7 had been discharged cured, and the rest were under treatment in the out-patient department. Only one-fourth of all the cases of diseased appendages, therefore, were removed by the greatest laparotomist the world has ever seen, and that has been the average in Dr. Johnson's own practice, three-fourths of his cases having been cured without having to be operated upon.

The removal of the ovaries and tubes is not the simple and harmless operation it has been painted. In a paper read by Dr. Skene, on the "Pathology and Treatment of Chronic Ovaritis," at the last American Medical Association meeting, he said that young persons stand removal of the ovaries badly. They become fat, irritable, indolent, and dissatisfied.

Dr. William H. Wathen, another veteran professor of gynæcology at Louisville, read a paper at the same meeting, entitled 'Suggestions on Abdominal and Pelvic Surgery." He thought there was too much laparotomy done, and too many men doing it; and that the appendages were sometimes removed for vague, nervous troubles, where there was no disease of the ovaries or tubes nor peritoneal adhesions. Such cases are often made worse and mutilated in a way that cannot be corrected. He was honest enough to say that, with greater experience, he could recall cases on which he had operated which he believed should not have been operated upon at all.

And last, if I am asked about my own humble experience, I would say that I can recall case after case in which operative treatment has been urged by the opponents of electricity, in disorders of menstruation, in which perfect cures have been obtained by the aid of this harmless remedy. Cases of amenorrhœa in stout women, who have been made to menstruate; in sterile women, who have been made to conceive; of women who have suffered untold agony at their menstrual period, and for the most of the time between it and the next; who have been made to see the flow come on absolutely, without the slightest pain,—so much so, indeed, that, instead of having a week or two of preliminary suffering, it has come on without their knowing it, and without even being prepared for it. As for cases of menorrhagia due to chronic endometritis, with or without fibroids, I have never known it to absolutely fail; and even one case, which I reported some time ago as a failure, called to see me, the other day, to say that the frightful hæmorrhages had never returned, that she had gained in flesh and weight, and felt

altogether so well that she had ventured to get married. Even in her case,—one of fibroid,—in which I was prevented from using full doses, on account of the tenderness of the appendages, the latter had been so much benefited that menstruation is now almost entirely free from pain.

In several cases of metrorrhagia, due to suspected commencing cancer of the uterus, in women who had passed the menopause and begun to flow again, I have arrested the bleeding with positive galvanization, so that it has not returned. Even for the troublesome menopause, for which the laparotomist can offer no relief, the conservative gynæcologist has, in fine-wire faradism, applied to the uterus, or even to the vagina, with the bipolar electrode, a most effective means of drawing the attention of the nervous system back to the pelvis and away from the brain.

I have already said that the electrical treatment of diseases of women has one element in it which prevents it from ever being looked upon with favor by the brilliant and dashing laparotomist, who can make or mar a woman's fate in the brief space of fourteen minutes,—and that is, that while it requires just as much diagnostic skill and antiseptic precautions as cutting operations, it unfortunately requires an enormous amount of time, comparatively speaking. But there is still another reason,—which I mention in no spirit of harshness, but simply as a fact, remembering that even those who follow our noble profession are only human still,—and that is, the tendency of patients, and even of most practitioners, to look with admiration and esteem upon one who operates, while he who, patiently, more than accomplishes the same results by other treatment receives but a scanty meed of praise. We see it in general surgery, even down to the smallest details. The man who has his right, bread-winning hand crushed in a machine speaks very little of the wonderful skill of the practitioner who carefully sews and splints and washes and cleans it up, and, after several weeks or even a month or two, discharges him cured, with his member deformed, but able still to earn; while no praise is too enthusiastic, nor fee too great, for the dashing surgeon who promptly, under an anæsthetic, slashes the patient's whole arm off. And although the question of a fee could hardly be considered as an inducement to operate, yet, when one considers that a patient will willingly pay two or three times as much for the work of an hour, or a few hours at the most (including the after-care), than she would be willing to pay for the thirty or fifty or one hundred hours required for the treatment of the same case by electricity, it is a severe test of human unselfishness to decide upon the slow and troublesome and unremunerative treatment by electricity.

So that, with many powerful arguments against it, it is a wonder that electrical treatment of diseases of women has made the progress it has. That it will progress still farther and still more rapidly in the future, I have not the slightest doubt. As I have said in other writings,

it has gone through the usual flows and ebbs of the tide, which carries with it popularity with the profession. Advocated with too much enthusiasm at first, when it was least perfect, it was soon condemned when it had much improved. It is now being taken up again with a more moderate, but still no less certain, belief in its possibilities; and I can easily see how, in the future, the very ablest men will be able to use it to the very best advantage, either by making the diagnosis themselves and prescribing the particular form of electricity to be carried out under their immediate control in an adjoining room to their office by a young assistant, who could afford to devote his whole time to it, or, by having half a dozen nurses, each in a separate room, with the proper appliances, and where the operator himself could start the *séances*, leaving the nurse to hold the electrodes and turn off the current at the proper time, while the operator could pass on to another and another room.

The time for treating cases by this method is not all consumed while the current is flowing. The most of it is taken up by the coming in and going out, the dressing and undressing of the patient, irrigation before the application and disinfection of the electrodes. Even this time can be considerably reduced with a little practice, and by having the patients take their antiseptic injections at home, when they are of a class on whom we can rely to do it effectually; also, by the patients being instructed to come prepared with warm, loose clothing, and without corsets, so that they can walk directly on to the operating-chair. With increased knowledge of what it can do, and with increased facilities for doing it, I feel confident that electrical treatment of disorders of menstruation will, at no distant day, reach as high a position in the favor of the profession as surgical interference holds now.

Amenorrhœa.

Cases of amenorrhœa—that is to say, arrest of menstruation in women who are old enough to menstruate, and who are not pregnant—sometimes cause us a great deal of trouble. The majority of them who have come under my care have been stout women, who were, at the same time, anæmic, although they were apparently otherwise in excellent health. They are generally indolent and disinclined to undergo any exertion, although this may be due to the quantity of fat beneath their skin, which renders their weight so great that it requires an exertion to move about. These women are generally sterile, and, having no children to think about, generally exaggerate the gravity of their symptoms, and, altogether, render themselves very unhappy. It is a question whether the obesity is due to the amenorrhœa, or whether the amenorrhœa is due to the obesity. I think it more likely the former is the case, that obesity is due to amenorrhœa. There would seem to be a deficiency in the nerve-stimulus to the generative organs, which become atrophied, or, at least, fail to develop. Other things being equal in the way of digestion and assimilation, while

there is no loss of blood by the uterus every month, that amount of blood is placed to the credit of profit-and-loss account, with the result of swelling the reserves; in other words, laying on fat. It only requires a small amount of adipose tissue to be deposited among the muscles of the organism, especially of the heart, to render exertion difficult, or, at any rate, unpleasant; so that these women will cease to take even their usual amount of exercise, with the result that there is a still further storing up of hydrocarbons in the form of fat.

On the other hand, it is just possible that menstruation may be prejudicially affected by the unhealthy conditions of the tissues,—such as are present in women who are very obese. It may be that a woman who has menstruated regularly and well may, by being deprived of exercise for various reasons, and at the same time being fond of hydrocarbonaceous food,—and, on the contrary, disliking, as many of them do, a nitrogenous diet,—rapidly put on fat not only under the skin, but among the muscular fibres of all other organs, the uterus included. It may also be that a great load of fat in the omentum and in the mesentery may so crowd upon the uterus as to diminish its vascular supply, the result being, equally, that menstruation is arrested.

Many of these stout women suffering from amenorrhœa have a great deal of pain at the menstrual period, which is in some cases due to a congestion caused by the weakness of the general circulation, while in others it depends upon the acute anteflexion of an undeveloped uterus; in others, again, it is neuralgic, and the pain is due to the poor quality of the blood,—for we know that neuralgia is the cry of the nerves for better nourishment.

Then, girls suffering from amenorrhœa, due to a slight cold or to overwork, generally become so anxious about their condition, owing to the suspicions of their friends or to the wide-spread idea that amenorrhœa is a dangerous symptom, that the periods are driven still farther away by the worry that this causes.

Then, again, women are ready to attribute any and every disease with which they are afflicted to the amenorrhœa if their periods happen to be absent; so that the conditions which cause the amenorrhœa in the beginning are still further accentuated in the end. Therefore, for psychical reasons, if not for pathological ones, it is often of the greatest importance to re-establish the menstrual functions as soon as possible if it has already existed, or establish it on a sound basis if it has not yet appeared.

In the majority of women with amenorrhœa hygienic treatment, combined with ferruginous tonics and saline laxatives, will bring on the periods in from four to eight weeks. This treatment, which is very effective in thin and pale girls suffering from anæmia, is not so effective in married women who are very stout. Fortunately, in their case we have a valuable means of developing the uterus and appendages by

causing a greater flow of blood toward them,—and that is the faradic current of tension applied with the bipolar intra-uterine electrode. I have had a great many such cases, principally in sterile women who have been married three or four years, and who, while having no periods, are becoming stouter and stouter. After from four to twenty applications of the bipolar faradism the menstruation has almost invariably been re-established; and after that the amount can be made to increase by continued applications of the faradic current.

In young girls who are being pushed with their studies at college, and whose brains are, consequently, using up all the blood that their enfeebled appetite and digestion can supply, amenorrhœa has a very special significance and importance far beyond the mere suspension of the menstrual flow, which in their case is rather conservative than prejudicial. It means that the generative organs are being starved at the very time that they most require a plentiful supply of good blood for their development. It means that the whole after-life of that unfortunate girl is to be overshadowed by the consequences; that its relaxed walls will allow the uterus to topple over, either forward or backward, causing endometritis and flexions which, in turn, lead to dysmenorrhœa. The deposit of fibrous tissue at the angle of flexion will cause the first stage of her first pregnancy to be unduly prolonged and exceedingly painful, and to be followed in the majority of cases by a tear, which, if it is not recognized and repaired before she reaches middle life, will in a great many cases lead to cancer of the cervix. So that it can be seen that amenorrhœa is a symptom of a very serious condition, and one which cannot be remedied too soon. It need hardly be said that the physician should, first of all, correct the faulty hygiene, and see that his patient obtains good food, good air, and proper exercise. Neither medicine nor surgery has any resources which can take the place of these. But having seen to this, and the patient having regained a fair condition of health without menstruation having made its appearance, he will do well to fall back upon the various forms of electricity in order to re-establish the menses, and also, at the same time, do what is still more important, restore the healthy nutrition of the uterine tissues.

Dr. Jenks, in his excellent work on "Disorders of Menstruation," p. 4, in treating of amenorrhœa, says that general galvanization applied to the uterus and over the ovaries stimulates the nutrition of these organs, and thus assists in their development and aids in the establishment of the menstrual flow; and he relates the following interesting case:—

Mrs. F., a robust, well-developed woman 32 years of age, consulted him with reference to the possibility of becoming pregnant. There was every indication of the development of the ovaries, but the uterus was imperfectly developed, its entire cavity measuring one and one-half inches in length. Menstruation had always been scanty, and for the two preceding years had barely made its appearance a few times; notwithstanding every month there was the molimen, accompanied by many distressing symptoms. For two years and a half she was treated, from two to four times per week, by galvanism and stimulating intra-

uterine applications. At the end of this time the uterine cavity measured a trifle over two and one-fourth inches, menstruation had become regularly established, and on returning for treatment it was found that the menses had not appeared at the expected time; therefore she was advised to have nothing done, as there were some symptoms of pregnancy. The surmise proved correct, and she has since borne two children.

General galvanization and faradization are of great benefit indirectly by curing the constipation which is the cause of the anæmia, which in turn produces the amenorrhœa. Most of the girls who have consulted me for this condition went from a week to ten days without a movement of the bowels. Their blood was saturated with poisonous gases, which caused such a disgusting fæcal taste that they could not bear the sight of food. We should never begin the treatment of any case of disordered menstruation without first remedying the chronic constipation.

Beard and Rockwell report a number of cases of amenorrhœa which were cured by various forms of electricity. One was a very weak and hysterical girl of 20, in whom the periods for six months before had been growing less and less, until two months before they had entirely stopped. Her menses returned after eight applications of general faradization extending over six weeks, without any other treatment.

Another was a single lady of 25 who, during four years, had been menstruating only two or three times a year, and had at the same time been increasing enormously in weight. She had been treated all that time with appropriate medicines, without effect. She was very plethoric and suffered much from fullness and oppression of the head, accompanied by cold feet and sudden hot flashes. After two months' treatment with general faradization and a few local external faradizations, the menses were completely and permanently restored, and at the same time there was a corresponding decrease of flesh.

Another case was a school-girl, whose periods had been suppressed for a year, who was completely cured by twelve general faradizations. A married lady, 35 years of age, had ceased to menstruate for seven months, when she was taken with serious reflex nervous symptoms. In this case general faradization failed, and recourse was then had to local faradization, with the result that a few hours after the second application menstruation returned and recurred regularly every month.

Mundé, in a very interesting book, "Electricity as a Therapeutic Agent in Gynæcology," relates a number of cases in which amenorrhœa of even several years' standing has been permanently cured by the application of faradism either externally to the utero-ovarian region or else to the neck of the uterus, and in some obstinate cases by means of a metal-ball electrode.

As for my own experience with electricity in the treatment of amenorrhœa, I must admit that it has been somewhat limited, for the reason that out of all my cases of this condition, numbering several hundreds, fully 90 per cent. were cured after one or two months' treatment on general medical principles, such as improving the hygiene and administering

iron and arsenic. Of the remaining 10 per cent. more than half suffered excessive pain with the molimen, or in some cases with a very scanty flow, and were therefore classed as dysmenorrhœa. As will be seen by referring to the latter topic in this article, most of these cases were cured by negative intra-uterine galvanizations. So that, out of my several hundred cases in which menstruation was either exceedingly scanty or absent altogether, not more than a dozen were deemed suitable for electrical treatment solely with a view to bring on the flow. In these I have employed the faradic current of tension—that is, from the long, fine, secondary wire—with the most satisfactory results, in some cases the flow becoming firmly established after two or three applications, although in the majority it required two or three applications a week for two or three months. In two or three cases in which the amenorrhœa was due to an infantile condition of the genital organs, a longer time was required. But I am satisfied that the most pronounced case can have her uterus so powerfully stimulated, by means of the intra-uterine bipolar faradization, that, eventually, it will attain a depth of two and one-half inches, and, other conditions being favorable, she will conceive and bear children. As I have always been reluctant to apply local treatment to unmarried women, most of my experience with electricity for amenorrhœa has been in young married women, who consulted me either because they were sterile or because they were totally lacking in sexual feeling. As far as the return of the periods and their subsequent arrest by pregnancy, I can testify positively; but with regard to the development of any passion I cannot speak very decidedly, as it is difficult to induce women to speak much about it. In two or three cases, however, treated by electricity, I have reason to believe that sexual feeling actually was experienced after many years of married life without it.

In an elaborate article which appeared in the June number of the *American Journal of Obstetrics* for 1890, Dr. Paul F. Mundé says, "I have been particularly pleased with the effects of the faradic current,—one pole in the uterus, the other alternately over the ovaries and uterus,—two to three sittings per week of twenty to thirty minutes each, continued from three to six months, in cases of deficient or scanty menstruation, where often two or three periods are passed without any show whatever occurring in large, fat women. I have seen, within the last three years, two instances of complete restoration to regular menstruation with, in one case, the occurrence of repeated conceptions, after eight years of sterile married life. In several instances I have also seen, after a similar course of treatment, a decided improvement in the tone of the sexual functions, as shown by an increase of sexual passion, for the absence of which these patients consulted me. It is almost needless to say these women were also sterile. I have been particularly impressed with the benefit of the faradic current, when used in this manner, on women who had become rapidly stout soon after marriage, and in whom menstruation

had correspondingly decreased in quantity and regularity ; they remained sterile at the same time. Of course, it requires that the treatment be continued for a number of months in order to achieve any positive results."

Dr. W. H. Walling, of Philadelphia, thinks that electricity has done more in the treatment of cases of dysmenorrhœa of long standing than any other form of treatment. He advocates general faradization as a tonic, together with local galvanic applications.

Hardon (*American Journal of Obstetrics*, October, 1888), in reporting eleven cases of superinvolution of the uterus following trachelorrhaphy in which menstruation was arrested, states that eight of them were treated by intra-uterine (fine-wire) faradism, with the result that menstruation returned, while in three which had no treatment menstruation did not return.

Scanty Menstruation.

In the majority of cases in which the menstrual flow is scanty inquiry will show that there are gross hygienic errors at work, especially in connection with a proper supply of food. The patients are very often either overworked and improperly-fed school-girls, or overworked and half-starved shop-girls, who spend their meagre salary on showy dress at the expense of a nourishing diet. For such patients electricity is not required. We shall do better by instructing our patients in the elementary rules of hygiene; by putting a stop to the continual eating of cakes and candy and pies and pickles by the wealthy school-girl, and to the scanty diet of potatoes and strong tea of the shop-girl,—a diet which in either case is totally unfit to sustain health. In a certain number of cases of married women, however, there are no gross errors of hygiene, but the flow is scanty because the uterus is in a condition of areolar hyperplasia, following an abortion or other causes leading to defective circulation. For these cases I have found the continuous current—negative pole in uterus, positive on abdomen, current-strength 50 to 75 milliampères—very effective, the uterus becoming lighter, rising in the pelvis, and the flow becoming much more profuse. A scanty menstruation is generally painful. More will be said about it under the heading of "Dysmenorrhœa."

Vicarious Menstruation.

Cases in which the menstrual flow ceases to appear at its natural location, or at least becomes scanty there and makes its appearance in a totally different organ, are not so rare as is generally supposed. Hermann, of London, however, in his article on "Vicarious Menstruation" (in Fowler's "Dictionary of Medicine," page 926), maintains that there is no such thing as vicarious menstruation. He says that cases recorded as examples of it fall under three groups : 1. Cases in which its only evidence is a vague statement from a patient, unaccompanied by dates. 2.

Cases in which patients lose blood from some diseased part, such as the lungs or stomach, and in consequence become anæmic and do not menstruate, and think the bleeding the consequence of the amenorrhœa instead of its cause. 3. Cases in which, as in purpura, the general vascular tension accompanying menstruation causes hæmorrhage from other parts besides the uterus; that is, menstruation is accompanied by hæmorrhage from other parts, not replaced by it.

On the other hand, so many examples have been recorded by various authors, and have even come under my own observation, that it must be admitted that cases do occur in which other organs than the uterus do bleed and do relieve the vascular tension which occurs at the menstrual epoch, and which hæmorrhage may fairly be entitled to be called vicarious. Any deviation from normal menstruation is so often the result of serious ill health that women very naturally associate the one with the other, although they invert the relation of cause and effect. They view arrest of menstruation with alarm, more especially if its disappearance is accompanied by so serious a condition of another organ as hæmorrhage. When the hæmorrhage occurs from the skin we may look upon it as a curiosity, but when it comes from the lungs or stomach it becomes of very considerable importance, if not to the patient's life, at least to her peace of mind. Although, as Hermann says, many of these cases are simply ones of amenorrhœa due to anæmia, caused by hæmorrhage from an ulcerated lung or stomach, yet there are others in which a vicarious hæmorrhage really does occur without there being the slightest evidence of disease in the organ which takes on this abnormal duty of relieving the periodical vascular tension. The following case occurred in my own practice about six years ago:—

Mrs. C., 35 years of age, had always enjoyed good health and menstruated regularly, although she had been married over ten years without ever having become pregnant. One day, while menstruating, she wet her feet, and the flow suddenly stopped and failed to reappear during the next two months. At the third epoch her vocal cords were so congested that she became aphonic and she had a slight brassy cough. On the date when her period should have come on she began to expectorate bright-red blood, which continued for nearly a week. This, of course, caused her intense alarm lest her lungs were seriously attacked with consumption, although I assured her, after a careful physical examination, that they were absolutely healthy. As I was not at that time acquainted with the value of electricity as an emmenagogue, I ordered pills of aloes and myrrh, which she took for about six weeks, with the result that her natural periods returned, the hæmoptysis ceased, and her voice was restored.

Another case was:—

Mrs. B., aged 21, who had begun to menstruate at the age of 13. It had always been scanty and exceedingly painful. For two or three days before it appeared a bloody perspiration came from the top of her head, and a bloody discharge from her eyes, nose, ears, and nipples, but from no other part of her skin. On examination the external genitals were found to be well developed, but the uterus was very small and sharply anteflexed. It was my intention to develop the uterus and draw the blood toward it by means of the negative galvanic current, but, owing to the patient's removal from the city, I lost sight of her ever since.

Jenks, in his excellent work, "Disorders of Menstruation," page 18, relates a case in which the menses were arrested in consequence of exposure during a sea-voyage, and in which there was an oozing of blood through the skin of the left cheek, lasting for three or four days and recurring every twenty-eight days. This periodic oozing continued for a period of over two years, normal menstruation never again occurring, when symptoms of phthisis began to manifest themselves, and the girl died in a few weeks.

It may be admitted that the principal importance of this curious aberration of function lies in the alarm which it very naturally causes, and we are therefore justified in doing more for its relief than we would otherwise be. The treatment should be very much the same as that of amenorrhœa. If the patient is a married woman, we need have no hesitation in applying electricity to the interior of the uterus for the purpose of attracting a flow of nervous fluid and blood to that organ, which in such cases is generally found to be undeveloped. If there be no dysmenorrhœa, the current from the fine-wire faradic coil will suffice, while it has the advantage of being easy to apply with Apostoli's bipolar intra-uterine sound, and not unpleasant for the patient. If, however, there is much pain at the menstrual period, the negative continuous current will be more useful, because it is a specially suitable remedy for the endometritis which will in such cases generally be present. The method of applying it will be found fully explained under the treatment of "Dysmenorrhœa."

In single women neither vicarious menstruation, nor scanty menstruation, nor amenorrhœa are sufficiently serious conditions to warrant our making a vaginal examination, nor to make such applications of electricity as require a digital vaginal examination. In their cases, however, we can do much with general faradization, local internal faradization, and local galvanism, with which many cases of cure have been recorded.

Dysmenorrhœa.

This term, properly speaking, means difficult menstruation, but is also applied to menstruation accompanied with pain. It is the symptom of a great variety of pathological conditions, and, in order that we may understand its treatment by electricity, we should first ascertain to which of the conditions the pain is due. We may, therefore, classify the various forms, according to Jenks, into (1) neuralgic, (2) congestive, (3) obstructive, (4) membranous, and (5) ovarian.

Neuralgic dysmenorrhœa is generally due to an insufficient quantity or inferior quality of the blood-supply. One of the best definitions for neuralgia in general is, that it is the cry of the nerves for better nourishment; and, as the process of menstruation is one that requires a large expenditure of nervous force, it therefore follows that its production in insufficiently-nourished organs is apt to be accompanied with severe neuralgic pain.

The first thing to do, of course, in such cases, is to improve the quality of the whole mass of the circulating fluid by means of fresh air, exercise, and proper food, which these patients do not generally care for, preferring all those things which are least nutritious. Among the means for improving the appetite and digestion is general faradization.

This is probably beneficial on account of the artificial exercise or gymnastics through which the muscles throughout the body are put; for wherever muscles contract they expel the used-up blood which they contain, and which is replaced by fresh blood brought in by the arteries, thus hastening on the circulation and increasing the metabolism in the tissues, the result being an increase in the digestive and assimilating processes. If the general faradization also include the toning up of the stomach and bowels through the abdominal walls, with the electrode applied to the abdomen and the other pole applied to the spine or inserted into the rectum, constipation will be relieved, or, in fact, cured, as I have many times noticed in patients treated by electricity; and this alone, as I have shown under the head of "Amenorrhœa," will go a long way toward improving the quality of the blood. But there is another way in which electricity may be of great benefit in neuralgic dysmenorrhœa when applied locally: either the galvanic current or fine-wire faradism undoubtedly acts as a local stimulant to the parts, increasing the activity of the trophic nerves, whose influence we do not too well understand, and improving the nutrition of the nerves of sensation, which alone are capable of transmitting pain. This remarkable power possessed by the faradic current of tension to relieve and even remove neuralgic pain has been denied by some and doubted by many, but for me there is nothing more certain. I recall at this moment many cases of pain in the pelvis, continuing long after the operation for the removal of the ovaries, which the operation had failed to cure, and which was more or less promptly cured by prolonged application of the current of tension to the inside of or to the neighborhood of the uterus with Apostoli's bipolar intra-uterine or vaginal electrode. In like manner I have entirely cured, without operation, neuralgic pains of other patients for whom abdominal section had been advised by my colleagues, and even formerly by myself. How it accomplishes this is still a problem which we are unable to explain. Some suppose that the rapid vibrations in the electric current disorganize the vibrations of the currents in the nerves called pain; others maintain that the current in a long, fine wire, flowing under very much greater pressure than the pain-currents in the nerves, drive these latter back and prevent them from traveling onward. Certain it is that only very rapid interruptions possess this anæsthetic effect. The duration of the relief, long after the cessation of the application, has been explained by the supposition that the tissues and fluids of the body act as an induction apparatus, or, rather, as a storage battery, which continues to emit an electric current for some time afterward. Jenks says

that, when there seems to be a lowered tone of the nervous system, nerve-tonics may be supplemented very advantageously by electricity; a light galvanic current down the spinal column for ten minutes, and a stronger current through the pelvis, or as nearly as possible along the course and about the terminus of the nerve, which is the pain-conductor. The sitting should not exceed twenty-five minutes, and often fifteen minutes is as long as the nervous patient can bear, especially in the beginning of treatment. In congestive dysmenorrhœa the relief, after the application of the continuous current, as described by Jenks, or by applying it with the positive carbon electrode in the vagina, due precaution being taken to cover the carbon with wet lint or absorbent cotton dipped in egg-albumen, as suggested by Goelet, is undoubted, many reliable authorities having reported instances of it. Probably the benefit is due to a toning up of relaxed fibres controlling the calibre of the capillaries, thereby diminishing the quantity of stagnant blood and increasing the quantity of arterial blood brought to the part in a given time; also, the toning up of dilated blood-vessels alone gives great relief, as I have many times found in varicose veins of the testicle, where a single application of 5 or 10 milliampères for ten minutes or a quarter of an hour will completely relieve the most excruciating pain of varicocele, the relief lasting from many hours to many days, or, in a few cases, even altogether.

In the obstructive form there is either a sharp flexion at the level of the internal os, which obstructs the flow of menstrual blood just the same as a kink in a fire-hose stops the flow through it, or else there is an organic stricture; or the stricture may be spasmodic; or the obstruction may be due to a fibroid polypus or tumor blocking up the cervical canal. No matter what the nature of the obstruction, the galvanic current offers many advantages for its treatment over any other remedy.

Fry, of Washington (*American Journal of Obstetrics*, vol. xxi, p. 44), sums up the superiority of this treatment very concisely in the following terms:—

Rapid dilatation, though not free from danger, has so far superseded the other methods that I select it to represent the class, and will compare its merits with those of electrolysis for the relief of sterility and dysmenorrhœa.

The degree of dilatation is not great. The objects chiefly sought are a moderate but permanent amount of dilatation. These, I claim, are secured by electrolysis better than by any of the above-mentioned methods. The advantages of electrolysis compared with rapid dilatation are:—

1. Its simplicity; no anæsthetics and no assistants are necessary. The treatment is carried out at the physician's office, and the patient is spared the mental suffering of having to undergo an operation. Many will consent to this method of treatment who will refuse harsher means. Rapid dilatation, on the other hand, unless imperfectly done, requires anæsthesia; the patient must remain in bed several days, and precautionary methods must be adopted to prevent the development of inflammatory complications. To say the least, it is a harsh method of treatment. Thomas, writing in 1879, styled it "shockingly brutal."

2. Its safety. It is devoid of any other danger, unless imprudently used. The electrode is made to traverse the cervical canal slowly; it is arrested at the contracted

portion until the electrolytic action permits it to pass without the use of force. By rapid dilatation some tearing of the cervical tissue is unavoidable. Inflammatory complications sometimes develop, and these require after-treatment, which delays and sometimes terminates all efforts to cure the stenosis.

3. The result is better. You must consider both the immediate and the remote effects. The immediate effect is favorable, because the galvanic current is in itself a valuable therapeutic agent, and often suffices to cure attending morbid states of the uterus. Neuralgic pains, uterine fixation and inflammation, hyperæsthesia, and atrophy of the mucous membrane often disappear without further treatment. The relief of dysmenorrhœa follows. What proportion of cases of sterility can be cured is a question for the future to decide.

Fry reports, in the same place, the following instructive case:—

A lady, who had been sterile for nine years, came to me with the external os tightly contracted, the cervix long and conical in shape, the body anteflexed, and the internal os contracted. Instead, however, of dysmenorrhœa there was very scanty menstruation,—almost amenorrhœa. Nothing but the local morbid condition could be found at fault. A prominent physician had performed rapid dilatation some years ago, and she had taken no end of emmenagogue preparations without benefit. I was consulted mainly on account of the scanty menstruation. Examination having revealed the condition described, I determined to apply electricity for its relief, as well as for that of the menstrual disorder. The effect of the faradic current was promptly manifested by increased catamenial flow. The galvanic current readily opened the cervical canal to the desired extent. Six months after the patient had come under observation she was impregnated. The success in this case could fairly be attributed to electricity, as it was the only remedial agent employed, and it succeeded after failure of rapid dilatation and generous internal medication.

That the negative pole of the galvanic current has the power in moderate milliampèrage to soften and dilate a stenosis of the uterus is proved by my own experience, and also the experience of many others.

In stricture of the urethra I have demonstrated, to my own satisfaction, that an olivary electrode three sizes larger than the largest which I could pass would slip through the stricture, after ten to fifteen minutes' gentle pressure against the stricture, with a current of only 5 to 7 milliampères flowing through it. Although I am not now engaged in such practice, some of my patients, for whom I made a few applications of this kind, felt so satisfied with its benefit that they have come and begged me to give them a few more applications of electricity to prevent the stricture from returning.

From the writings of Steavenson, Newman, and many others we see that it has been proved of great benefit in strictures of the œsophagus and lachrymal ducts. Dr. J. Ford Thompson (*American Journal of Obstetrics*, vol. xxi, p. 79) relates a case of stricture of the rectum which was cured by electricity after every other treatment, including operation, had failed.

I cannot better describe the method of application than to quote again from Fry's excellent paper:—

Bimanual examination is first demanded in order to ascertain the condition of the pelvic organs, the size and position of the uterus, and the presence or absence of para- or peri-metritis. The patient can be placed in the semi-prone position and the cervix brought into view with the Sims speculum, but ordinarily the dorsal position answers every pur-

pose, while permitting more readily the application of the external electrode. The bi-valve or tri-valve speculum is used when the latter position is assumed, and the direction and course of the cervical canal explored with a sound. If the tenaculum is used it must be only to steady the cervix. Force must not be used either to draw down the uterus or to push up the electrode. The positive electrode consists of a soft sponge about the size of the palm, and is placed either over the fundus uteri when in the former position, or the patient may lie with it pressed against her spine at the lower lumbar or upper sacral regions. The negative electrode which I have employed consists of an insulated copper wire with olive-shaped tips of different sizes. One of these, somewhat larger than the lumen of the strictured passage, is selected and screwed upon the extremity of the insulated wire. The circuit is completed when the olive tip comes in contact with the tissues of the cervix. If the external os is the seat of contraction, the olive tip is held gently in contact with it a few minutes, until absorption removes the obstruction and the electrode passes without forcible pressure. It is then carried slowly along the canal and through the internal os. If any obstruction in its passage is met with, the electrode must be held until the destructive effect of the current has overcome this likewise. At the next *séance* a larger-sized olive is passed in the same manner, and so on until the requisite amount of enlargement is obtained. The sittings should last from eight to fifteen or twenty minutes, and the applications be repeated every five or seven days.

In my own practice I deviate slightly from this proceeding. The patient before coming to my office is ordered to take a large cleansing douche. On entering she at once takes her seat upon the Harvard chair, which on being tipped back places her in the dorsal position, with her feet in the foot-rests. If it is her first application a careful bimanual examination is made, to exclude pelvic tumor or other diseases. The pelvis being found clear, the warmed Cusco speculum is introduced, the blades separated, and the vagina swabbed out with a piece of sublimated absorbent cotton on the dressing forceps. An ordinary uterine sound is held for a few seconds in the flame of the spirit-lamp, dipped in water to cool it, covered with a piece of clean rubber tubing, kept in weak carbolic for the purpose, to within two and one-quarter inches of its extremity, dipped in glycerin, and gently introduced into the cervix. While I am doing this the patient has been loosening her clothes and has applied the Apostoli clay electrode to her abdomen. The clay is kept warm day and night without drying by turning it face down in a deep soup-plate half filled with warm water, which is kept on the back of the kitchen-range ; by this means it never dries up, because the evaporation from the plate condenses on the clay and drops back into the plate. I then connect the clay with the positive cord of the battery and the handle of the sound with the negative cord, place a sand-glass (which just takes five minutes to run out) in the patient's hands, and gradually turn on the current to 10 milliampères. The sound has probably stopped at an inch or an inch and a half, and no amount of pressure, even if I employed it (which I do not), would make it go any farther before the electricity was turned on. But with the electricity things are very different ; the sound merely guided in the right direction by the hand in a minute or two slips along by its own weight, often by little jumps of a quarter of an inch, until it reaches the internal os. There it may remain for a minute more,

when something is felt to relax before it and the sound then makes a big jump of an inch, and I know that it has passed up to the fundus. By the end of four minutes the cervical canal has become so much enlarged that it no longer gives any trouble to run the sound back and forth, and I take care not to leave its extremity pressing on the fundus. After the first two minutes or so I increase the current-strength to 20 or 30 milliampères, or if the uterus is a very long one I even go to 40 or 50, provided that the patient assures me that it does not cause her the slightest pain. Or if at any time during the five minutes it should do so I at once reduce the current, as I take it that pain is due to cauterization, and this I wish to avoid. I have another reason for not hurting her, namely, in order not to make her an enemy of this method of treatment. Some of its opponents have laid great stress on its being so painful, not understanding that there is a vast difference between the mild currents used in dysmenorrhœa with the sound gently slipped into the uterus and the powerful and destructive currents applied by puncture in cases of fibroid.

When the patient has informed me that the five minutes have passed I turn off the current, remove the sound, place a boro-glyceride tampon against the os uteri, remove the speculum, disconnect the abdominal electrode and replace it, face down, in its plate of water, tip up the chair, and the *séance* is finished. By having all the electrical cases come on Tuesdays and Fridays, about the same hour, I have been able to get through with four per hour, and I hope to reduce the time still more by having the patients instructed and undressed and dressed by my nurse, in an ante-room. I lay some stress even on this point, for the large amount of time which this method is supposed to, and really does, take up has been one of the real, if not avowed, causes of the hatred which many great gynæcologists naturally have for it. The other objection is the care of the battery. Just when they want it most, they tell me, something goes wrong with the battery; and, as one of them told me, "I feel like a fool, and have to send the patient away." But in every large town the Bell Telephone Company or other electricians will undertake to keep the battery in order; and, to absolutely avoid failure, it is better to have two batteries, of 30 cells each, in the cellar, with separate connecting-wires running up to the office. You will thus have four binding-posts close together on the wall or table, marked P. 1st N. and P. 2d N. I have two batteries of 60 cells each, one of Leclanché cells and the other of Law cells, and also two rheostats; so that if anything happen to one, I simply discard it for the time and use the other. When I only had one battery, I admit that I was often greatly annoyed to find that my battery would not work when the waiting-room was full of patients who came for this treatment; and under such conditions one is not in the proper frame of mind to go down to the cellar and calmly survey the situation. An irascible *confrère* once told me that he felt far more inclined to pick up the wood-axe and chop the battery to pieces

than to quietly test the one hundred and twenty connections. I may say here that I have found the Law cell most satisfactory in this respect, the only precaution I have had to take being to tighten up the binding-screws once or twice a month, and to put in fresh liquid once a year.

As I have already said, I employ the ordinary sound instead of the olive-tipped bougies, for the reason that the larger the surface of metal exposed the higher the current that can be given without pain and without cauterizing. I wish to treat as much of the total surface of the endometrium as possible. Our object is not to cauterize, which would be the case if we employed as high as 25 milliampères per square centimetre, as Martin as shown; for cauterization or destruction of tissue is always followed by a cicatrix which naturally contracts. By using a moderate current, on the contrary, the stenosed canal is dilated rather by the stimulus of the vital processes or absorption of inflammatory exudation, which, in most cases, is probably the cause of the trouble, as it is generally admitted that at the angle of an acutely ante-flexed uterus there is an obstruction of the circulation, which soon leads to an exudation of lymph, which sooner or later becomes organized. It is probably by setting up absorption of this effusion that the negative pole of the galvanic current produces its marvelous effects.

There is another way in which another form of electricity—namely, the faradic current—may be of great benefit in dysmenorrhœa due to ante-flexion of the uterus. As I have shown in my paper, read before the Ninth International Congress at Washington (" Transactions," vol. ii, page 664), deformities such as anterior and posterior flexions of the uterus are due to inherent weakness of the vertical fibres of the anterior and posterior walls, which should be strong enough to hold that hollow muscular organ up straight, like a metal tube, but which, owing to the blood, upon which they depend for nourishment, being exhausted by the demands made upon it by the brain, and even lacking the nervous impulse, without which no muscle contracts, these vertical muscular fibres lose their tone and allow the uterus to topple over. It seems to me, therefore, the most rational treatment, if we could have the patient employ it, would be to put this weak and toppling-over mass of relaxed muscle through such a course of gymnastics as would increase the nutrition of the muscles and thereby enable the organ to hold itself up straight. In other words, I would treat a bent uterus as I would treat a bent boy or girl,—by developing their muscles with work. Every time a muscle contracts its nutrition is improved; and when its nutrition is improved it becomes stronger. By applying coarse-wire faradism with slow interruptions,—one pole filling the whole uterine canal and the other pole on the abdomen, or even with both poles in the uterus,—we can make its fibres contract a great many thousand times in the course of a quarter of an hour's *séance*. The result would be that, after a certain number of *séances*, the organ would be sufficiently strong

to hold itself up, and the kink in the uterine tube, which gave rise to so much suffering by obstructing the outflow, would be straightened out and remain so.

At the discussion of the Obstetrical Society of Cincinnati on a paper by Dr. E. W. Mitchell, on the treatment of dysmenorrhœa (reported in the *American Journal of Obstetrics*, vol. xxiii, p. 327), there was a general consensus of opinion that in every case of dysmenorrhœa there was a hyperæsthesia of the endometrium in the region of the os internum and the uterine fundus. I have noticed this myself in every case in which, for one reason or another, I have found it necessary to pass the sound. The moment the tip of the sound touches the level of the internal os the patient complains of a sharp pain extending into the hips and toward the back, which she compares to her usual pain of menstruation. This condition, I therefore feel certain, is one of the principal causes of dysmenorrhœa. The pain at the internal os is, of course, increased whenever the uterus makes an effort to squeeze something past it; while the pain thus caused is transmitted to the spinal cord, where it is transferred to a motor cell, which sends down the reflex-contraction order to the sphincter of the internal os, which, consequently, spasmodically contracts. The pain caused by the contraction or bringing together of opposite hyperæsthetic surfaces, of course, sets up still tighter spasms,—and so the vicious circle goes on.

As Dr. Wiley, in his excellent article on "Menstruation and its Disorders," in the "American System of Gynæcology," says, "In the majority of cases the suffering is caused by the hyperæsthetic condition of the endometrium, especially at or near the os internum, often combined with more or less stenosis or induration at this point,—stenosis due to degeneration, contraction, and atrophy, the result of imperfect development, followed by disease; or disease, followed by induration, atrophy, and contraction. The hyperæsthesia may induce spasmodic contraction, which may cause the pain without the presence of any special induration or stenosis at or about the os internum." The association of painful menstruation with peri-uterine diseases he would explain by the tendency of this latter to set up intra-uterine disease. Such being undoubtedly the condition present in dysmenorrhœa, it is not difficult to understand the manner in which galvanizations effect so much benefit. The intra-uterine electrode, with a sufficient galvanic current passing through it, benumbs, or perhaps even destroys, the congested and exuberant mucous membrane. The hyperæsthesia being thus put an end to, the vicious reflex contractions also stop, and thereafter the flow escapes without any difficulty.

This factor of spasm at the internal os, from whatever cause produced, has not received the attention it deserves. It is much more often the cause of obstruction than is stenosis of the canal. I have been very much struck with this in my cases of fibroid tumor, who came to me with their

menstruation causing them the most fearful pain, although the canal was not stenosed; and yet, after from ten to thirty applications of the galvanic current, generally the positive pole in the uterus, menstruation would come on absolutely without pain; notwithstanding that the strong current which I had employed to diminish the fibroids had had the effect of causing in some cases a severe stenosis of the cervical canal, nevertheless menstruation came on absolutely without pain, and several of them even became pregnant.

Dr. Robert Bell, of Glasgow, stated (*British Gynæcological Journal*, 1886) that he found endometritis present in most of one thousand cases of dysmenorrhœa examined by him.

Now, for the treatment of endometritis there is probably no method or means that has ever been discovered more effective than the intra-uterine application of the galvanic current. Apostoli, in his book entitled "A New Treatment of Chronic Metritis, and Especially of Endometritis, with Intra-uterine Galvanic Cauterizations," clearly proves its value; while in the "Carlet Thesis," which was inspired by him, he fairly records a very large number of cases of this condition, generally accompanying myomas in the uterine wall, which were absolutely cured by the intra-uterine application of the positive galvanic pole.

It would probably be no exaggeration to say that one thousand skilled witnesses could be found in different parts of the world to testify, from their own experience, that intra-uterine galvanizations cure endometritis; and if endometritis can be shown to be the principal cause of dysmenorrhœa, it becomes easy to explain the otherwise almost miraculous results of this treatment. That both the positive pole of the galvanic current in the uterus, as held by Massey, and the negative pole, as held by Apostoli, Goelet, and the writer, are effective in the treatment of dysmenorrhœa is an undoubted fact. How they are so is a question which may give rise to much discussion.

It has been observed by Apostoli and the writer that the employment of high intensities, with the sound in the uterus attached to the positive pole of the battery, has been invariably followed by atresia of the cervical canal. At the same time those patients, who were all suffering from dysmenorrhœa as well as menorrhagia, were cured of both of these sometimes, instead of the latter being rendered much worse by stenosis of the cervical canal. For a long time I treated cases of dysmenorrhœa with the negative pole in the uterus, because I had noticed it had a peculiar dilating effect, and at that time I believed that dysmenorrhœa was always due to mechanical obstruction; but the experience of Massey in curing dysmenorrhœa with the positive pole in the uterus would go to prove that dysmenorrhœa is most often due to endometritis, for which the positive pole is an almost infallible remedy, rather than to mechanical obstruction, which would be very much increased by the contracting effect of positive galvano-cauterizations.

One of Apostoli's rivals—although a former pupil of his—has been claiming of late that he has obtained as good results by extra-uterine application of galvanism as have been obtained by the master with the intra-uterine applications; and he has claimed originality for this method. Apostoli himself, in a communication to the *New York Medical Record*, September 8, 1888, pointed out that uterine hæmorrhage might be arrested without introducing the sound into the uterus, simply through its tonic action on the parenchyma of the uterus, whereby the blood-supply to the engorged mucous membrane was partially cut off; but he also pointed out that this method of employing electricity was much slower and less decided in its results, and the patients were more exposed to suffer a relapse.

Another argument in favor of dysmenorrhœa being due to endometritis rather than atresia is that sterility has been associated with dysmenorrhœa in a great many cases, and, notwithstanding this, a considerable number of patients, formerly sterile, became pregnant after having received a course of intra-uterine galvano-cauterizations. Apostoli himself has had no less than thirty patients who had subsequently become pregnant, while I have had six in which the same result followed.

I have, therefore, come to the conclusion that sterility is more often due to endometritis and the consequent alteration in the secretion from the uterine and cervical mucous membrane, so that it has become acid or otherwise fatal to the life of the spermatozoa, rather than to stenosis of the cervical canal. This fact is supported still further by my experience with many cases of sterility before I had become acquainted with the galvanic current in the treatment of endometritis. I have generally noticed, in cases of sterility, that there was a good deal of uterine and peri-uterine tenderness, which I used to treat on general principles, such as reducing the congestion of the uterus by local depletives and curing constipation. About 70 per cent. of the cases of sterility subsequently became pregnant with no other treatment than that which cured the inflammation; so that I may conclude that either positive or negative applications will be effective in the treatment of both dysmenorrhœa and sterility. Mundé says ("Minor Surgical Gynæcology," 1885, p. 234), "I have also seen decided benefit from mild intra-uterine galvanization in neuralgic dysmenorrhœa which had resisted dilatation and all other topical measures."

In the previous page of the same work he reports very gratifying results, in neuralgic dysmenorrhœa, from the galvanic current, the negative pole, in the form of a ball electrode of metal covered with leather, being introduced into the vagina, and the positive on the abdomen, sacrum, or hip.

Mundé was one of the pioneers in electrical work in gynæcology, and it is gratifying to notice that, even so long ago as 1885, he was a firm believer in its great value as an alterative. In speaking of its application

to the endometrium, he said: "Its alterative effect is exerted not only on the mucous membrane, but on the whole uterus, and is accompanied by a very grateful, soothing influence on the nerves."

This soothing effect was illustrated in one of my recent cases of dysmenorrhœa in a very amusing manner. The patient was a young married woman from a country town near Montreal, and had had very little faith in doctors. As soon as I had introduced the sound and turned on the current she began screaming "You are giving me chloroform! You are putting me to sleep! I don't want chloroform! I won't take chloroform!" I had the greatest difficulty in pacifying her, and even after five minutes of laborious explanations she looked as incredulous as ever. She afterward explained to me that she thought I was giving her chloroform because such a sleepy feeling came over her. With the strong currents that we sometimes employ for the purpose of arresting hæmorrhage there is no danger of the patient thinking that she is taking chloroform; the feeling is far from pleasant, although not generally actually painful, but with the mild currents, which are all that are required in treating dysmenorrhœa, I have observed this soothing effect of the continuous current.

At a recent meeting of the Montreal Medico-Chirurgical Society this soothing effect of the current was doubted by an eminent oculist, who stated that in using it for opacities of the cornea he had found it so irritating that the patients could hardly endure it even with cocaine. As I pointed out to him, the electrodes he uses are exceedingly small, and as he had an unreliable galvanometer he was probably using far too strong a current, which in such cases should not exceed 1 or 2 milliampères.

Dr. McGinnis, who had charge of the electrical department of the New York Women's Hospital, states that the results have been so satisfactory when he has resorted to the galvanic current that he has now entirely abandoned any other treatment. He thus describes the method he employs in such cases: "Having thoroughly douched the vagina with an antiseptic solution and inserted the forefinger of the left hand into the vagina and the os uteri found, the intra-uterine electrode should be carefully run along the finger and introduced into the uterine canal up to the fundus. I cannot lay too much stress upon the importance of exercising the utmost care and gentleness in this procedure, as any rough handling would be apt not only to increase the existing inflammation, but cause a peri-uterine one. The clay having been placed upon the abdomen over the fundus and the negative conducting cord connected with it, the positive cord should be attached to the electrode *in utero* and the current turned on so gradually that no shock will be felt by the patient during the increase of it, which may be accomplished by means of a rheostat. The strength of the current should depend upon the resistance of the skin and the sensibility of the patient, never using more than an inflamed organ can bear with little discomfort and never causing severe pain." He says

he has generally been able to use 30 milliampères at first for a *séance* of three to five minutes, and has increased it as well as the length of time at each successive treatment. The current should then be very slowly shut off and the electrode withdrawn, the same gentleness being used as upon its introduction, after which, if the patient can rest for a time, it will be to her advantage. The good results of this proceeding, if done in this manner, are a surprise to those accustomed to the older methods of iodine, carbolic acid, etc.

MEMBRANOUS DYSMENORRHŒA.

In this condition the lining membrane of the uterus has failed to undergo the process of disintegration, or coming away in a liquid form, as it generally does. Whether this is due to a form of endometritis, causing it to become so thick and strong that it is able to resist the tendency to undergo fatty degeneration, which I think is the most probable cause, or whether it be due to some disorder of the trophic nerves which preside over the periodical nutrition and denutrition of the endometrium, there is no doubt that the suffering is due, for the most part, to the frantic efforts of the uterus to expel this foreign body, which is much too large to escape with ease through the internal os.

For these cases, in which, after excruciating pain, an entire cast of the uterine cavity is expelled, the negative pole of the continuous galvanic current in the uterus has been found to be of the greatest benefit. The sittings should begin the week before the expected period, and should be repeated every day or two, each sitting lasting ten minutes, and a current-strength of 50 to 100 milliampères being employed.

The *rationale* may be explained in three ways: First, the thickened endometrium is so disorganized or broken up by the caustic action of the negative pole that it easily comes away in shreds, as would be the case after the application of an alkali like caustic potash; second, the well-known softening action of the negative pole may so relax the internal os that quite large pieces of membrane may be able to escape without being noticed; third, the interpolar action of the galvanic current may so affect the trophic nerves as to hasten the process of fatty degeneration and consequent softening. That it occasionally accomplishes this, I have over and over again demonstrated in cases of subinvolution of the uterus after miscarriages and confinements, in which I have seen the application of the negative pole of the continuous current to the interior of the uterus, the positive being on the abdomen, followed by a reduction of one and even two inches in the depth of the uterus. It may be said that this was due to the uterus contracting under the stimulus of a foreign body, whether an electrode or anything else, and that the same result would have followed the introduction of the sound alone; but, in some of these cases which are of very long standing, there was a great increase of the

areolar tissue, and yet, even in these cases, the uterus did not fail to become smaller.

Although I believe the first of these three reasons to be the most important, I think the benefit of the negative galvanic current is due to all three of them combined. Rapid dilatation and curetting, performed under the most rigorous aseptic conditions, have long been advocated for the treatment of this painful affection, and, in most cases, with success; but the negative galvanic current does the same thing in a slower and much more gentle way, requiring neither anæsthesia nor subsequent confinement to bed.

Marion Sims, in his "Clinical Notes on Uterine Surgery," reports the following case :—

Mrs. —, aged 32, married at 24, sterile, had dysmenorrhœa for some years before marriage, worse after. Her sufferings were excruciating for about two hours on the second day. She had, in the course of twelve years, been treated by sixty different physicians without permanent benefit,—the largest number I ever knew any one person to consult. She had been under the care of many of the most eminent men in at least five or six of the great capitals of Europe besides her consultations at home. I saw her in January, 1857. Her general health was good; her only trouble seemed to be the much-dreaded dysmenorrhœa. The uterus was of normal size and in proper position; os and cervix both small, but not indurated. I inserted the sponge-tent, but found no polypus, no fibroid, and no flexure of the canal. Three days after (January 12th) the os presented precisely the same appearance that it did before the use of the tents. The next menstruation was quite as painful as the last, if not more so. As the canal was straight and the cervix soft, I would hardly have expected severe pain, although the os was rather small,—yet I did not know what else to do than to incise the os and cervix, hoping that some benefit might be derived from it. Accordingly, the operation was performed on January 22d, and the parts were healed before the next menstrual period; but the pain was still the same, and so continued for three or four months in spite of treatment. I was now quite perplexed. I had used the sponge-tent, and found no polypus; I had then enlarged the cervical canal, without the least improvement,—but the symptoms were so evidently those of mechanical obstruction that I concluded to make an exploration of the cavity of the uterus. I accordingly introduced a small sponge-tent, and on its removal I passed another larger and long enough to enter the cavity of the womb. On its removal I had the satisfaction of finding and bringing away a polypus which was but little larger than a common garden-pea. The violent, agonizing pain always supervened on the second day of the flow. When I first felt the tumor it was protruding through the os internum after the removal of the tent, but, by the pressure of the finger, it instantly slipped upward, and I could not touch it again until the finger was gently forced through the os internum to the fundus, when I fortunately seized it with the forceps and brought it away. My explanation of the pain is this: by the second day coagula formed about the tumor, which pressed it downward, its slender pedicle yielding until it blocked up completely the os internum just like a ball-and-socket valve. Then would come the violent spasmodic throes, continuing for two hours or more, until the tumor either dilated the contracted part or was compelled to retreat again into the uterine cavity by displaced coagula driven between it and the posterior face of the uterus by the expulsive efforts of the organ.

The case illustrates the necessity of a very thorough investigation before a correct diagnosis can always be arrived at in obscure cases. The leeching, the physicking, the blistering, the anodynes, the pills, the mountain-excursions, the sea-bathing and sea-voyages that this poor patient suffered and endured for years were almost incredible. As contemptible as the little polypus was,—it took me nearly four months of empirical observation to find it,—it was the source of all the mischief.

As I read of this case, which impressed me very much, how I longed that it might have come under my care since I have been using the negative galvanic current in so many of my cases of dysmenorrhœa! Although I might not, more than the talented and skillful author quoted, have recognized the nature of the obstruction, I feel sure the little polypus could not long have resisted the persuasive influence of the negative galvanic pole, and that, after one or two applications, nothing would have remained of it but the place from which it grew. Although it is a poor claim to make in its favor, that with it an unskilled workman can often produce better results than the most skilled gynæcologist without it, yet it is the case. This, indeed, has been one of the detriments of this method of treatment, that so many have thought an outfit of electrical apparatus would take the place of that diagnostic acumen, in determining the nature of the disease, which can only come from long and patient experience.

As far as the dysmenorrhœa due to inflamed ovaries is concerned, it may be recognized by the exquisite tenderness to pressure and sensation of nausea accompanying the vaginal examination. Dr. McGinnis is of the opinion that, if the advantages of electricity were more generally known, it would be the exception for the patients to be hurried to the operating-room to have their organs removed, when the grave questions of future maternity, prolonged convalescence, and risks were taken into consideration. He thinks we should make an honest effort to cure the disease by treatment before consigning them to the knife. His treatment consists in placing a soft, pliable electrode over the inflamed ovary, and a similar one beneath the lumbar region as the patient lies on her back. They are then connected with a faradic battery, and a current as strong as can be borne without pain is turned on gradually, the *séance* lasting eight minutes. After a few treatments it will be found that the ball electrode, connected with the positive pole, can be tolerated against the ovary, the negative one being on the abdomen, and the current of tension used thrice weekly. He concludes by saying, "The safety and ease of application, as well as its lack of terror to the patients themselves, in comparison to operation for the relief of their suffering, cannot fail to commend itself for a fair trial to those who seek the advancement of conservative gynæcology."

TUBAL DYSMENORRHŒA.

Cases of tubal dysmenorrhœa from contraction of the orifices of the tubes or from the tubes being bound down by pelvic exudation are by no means rare. They are generally, if not always, the result of gonorrhœal pelvic peritonitis, or of infection of the peritoneum after a dirty or septic miscarriage or confinement. A few drops of pus exude from the fimbriated extremity of the Fallopian tube, and in order to save the general peritoneal cavity from infection, which would

result in death, a local exudation is rapidly thrown out, which walls off the poison, limiting it to a greater or less extent of the pelvic peritoneum. Very often, however, before this has been accomplished the tube and ovary of one or both sides will have been included in the exudation area; this lymph generally becomes organized, forming cicatricial tissue of new formation. Like all cicatrices it begins to contract, and this process continues until the tubes are firmly bound down. At the menstrual period the fimbriated extremity of the tube places itself over the ripe Graafian follicle, so that when the latter bursts the escaping ovum and liquor folliculi are swallowed by the open mouth of the tube, and passed by a true peristalsis along the tube into the uterus. The cilia lining the tube are placed there rather for the purpose of preventing the entrance of spermatozoa than to wave along the ovum, as was formerly supposed. This vermicular action of the tubes has been denied by some, but without reason, for it is certain that the tubes are composed of successive layers of muscular fibres arranged very similarly to those in the intestine, and we may be sure that they would not be there unless for the purpose of peristalsis.

I have had considerable experience with cases of this kind, which has led me to come to the deliberate decision that the constant current will cause extensive adhesions to be absorbed. Like many others at first I could hardly believe the statements of those who asserted that such was the case, and it was with little expectation of seeing any results that I commenced the treatment of all such cases with the galvanic current, generally with one pole in the uterus, but sometimes with it merely in the vagina, pressed gently but firmly against the adherent appendages. In some cases the inactive pole was placed on the abdomen and in others on the sacrum, whichever position was most likely to include the diseased parts within the circuit of the current. Many of these cases had been urged to have laparotomy performed by others and some even by myself, and yet after from five to fifteen treatments the majority of them have remained free from symptoms for three or four years. In one of them, with the uterus firmly bound down in retroversion, although the exudation was nearly all absorbed, I was never able to replace the uterus, but the patient regained her health and strength and only requires to make two visits to my office, about every three or four months, for an application of iodine in order to keep her pelvis in fair condition. I have offered to perform hysterorrhaphy, but she declines as long as she can keep so well with so little trouble. In the cases above mentioned as relieved, the patients were nearly all suffering from dysmenorrhœa, and the appendages could not be outlined, apparently being imbedded in an exudation of plastic lymph. After a few applications the boggy swelling gradually began to grow smaller and the appendages could be outlined, and at the next period the pain was much less severe, and finally menstruation became painless and the uterus fairly movable. In the light of

our present knowledge of the cause of pelvic peritonitis and its frequent dependence upon pus exuding from the tubes, I cannot recommend the treatment by galvanism as the one to be chosen; removal of the pus-tubes is certainly the preferable treatment. But we occasionally have cases in which the condition of the patient is so bad that operation offers but little chance of recovery, and others who positively decline abdominal section. In such cases galvanism is a safe and excellent palliative treatment.

The following cases, only a few out of nearly a hundred of dysmenorrhœa cured by electricity, will no doubt prove interesting:—

CASE I.—Miss W. was sent to me June 3, 1888, by Dr. Reddy, with a uterine fibroid and enormous hypertrophy of the cervix. Her sufferings every month were unendurable. She had been employed as cook in a private family, but had to give up her situation as during menstruation she was totally incapacitated. She described her pain as agonizing, her screams being heard all over the house. I gave her two applications a week from then till July 28th of the same year, less than two months, when she reported that she had had a period absolutely free from pain. I continued to treat her for another month, but she has never had a painful period since and was still menstruating regularly up to a few months ago, when I saw her last, in perfect health and doing all the catering and cooking for a large boarding-house.

CASE II.—Mrs. D., a nullipara 46 years of age, was brought to me in June, 1888, by Dr. Jeanotte. Menstruation was always painful, but became much more so since her marriage, growing worse and worse until for the last ten years she had to be kept under the influence of an hypodermatic injection of morphine night and morning for eight days every month. This had completely broken down her general health. The cervical canal was so blocked and tortuous that I was unable after six sittings to introduce the sound farther than one and a half inches. I then turned on the current, when, to my surprise, the sound slipped in a distance of five inches. This was the first time I had observed what had been known already for a long time,—that the negative current had a marked dilating influence on a stenosed canal. After sixty-five applications she was discharged cured of her fibroid and her dysmenorrhœa, and six months later Dr. Jeanotte reported to me that menstruation was regular like a healthy girl's and absolutely free from pain, never having had a dose of morphine since commencing the treatment. I have since heard that she has remained well ever since.

CASE III.—Miss B. Endometritis, menorrhagia, and dysmenorrhœa, cured by eight applications of the positive pole, which I employed in this case on account of the hæmorrhage.

CASE IV.—Failure with rapid dilatation repeated twice, cured by seven applications of negative galvanism. Mrs. T., aged 25, began to menstruate at the age of 12, was regular every four weeks and lasted three days, but has always been, from the very beginning, terribly painful. She has been married two years, but has never been pregnant. I performed rapid dilatation a year ago according to Goodell's method, gradually extending the blades of his instrument during twenty minutes until they registered the distance of an inch and a half at the ends of the blades in the uterus. The next period was even more painful; so before the next one I again dilated the uterus to the full extent of the instrument and endeavored to introduce a glass stem-pessary, but owing to the rapid and powerful contraction of the internal os I was unable to do so. In January of this year she returned worse than ever, and I therefore gave her an application of negative galvanism, with the result that the next period, which came on in a few days, was only half as painful and being the easiest she had ever had. After this period was over I gave her six more between this and the next one, with the result that her flow came on without her knowing it and continued so for three days, absolutely without pain.

CASE V.—Mrs. G., aged 27, married five years, no children, and never pregnant, first consulted me early in March of this year. Menstruation had begun at the age of 13, and

had always been very painful, but has been much worse since her marriage. Uterus small and sharply flexed forward and to the right. After five intra-uterine applications of about 25 milliampères negative galvanism next period came on without her knowing it. Uterine and peri-uterine tenderness greatly diminished, and she feels better generally than she has done for years. Still under treatment.

Case VI.—Mrs. O. While writing the history of the previous case a lady walked into my office to engage me to attend her in her confinement. I recognized her as an old patient, and, on hunting her up in my old case-books, I found her name and the following history: She came under my care in March, 1888, and was then 26 years of age, six years married, and never pregnant. She had been under the care of a surgeon for some time for dysmenorrhœa without benefit, but she only left him because he urged her strongly to have her ovaries out, and this she was reluctant to do because it was the great ambition of her life to have a child. She had always suffered from dysmenorrhœa ever since puberty, but the suffering had become almost unendurable since her marriage, while locomotion and coitus were exceedingly painful. On examination I found the left ovary enlarged, prolapsed, and very tender, the uterus inflamed, and the cervical canal small and blocked with catarrhal secretion. Her periods were lasting eight to ten days. I applied fine-wire faradism to the vagina with the bipolar electrode on the 19th, 22d, and 29th of March. Her next period only lasted two days, and the pain only lasted four hours instead of several days. On April 16th she had her first intra-uterine application of negative galvanism, the sound entering with great difficulty, but coming out very easily. The next menstrual period was almost free from pain, but I gave her negative galvanism again on the 2d and 9th of May, 1888, after which I lost sight of her for two or three years, when I saw her on the stairs of the Woman's Hospital for a few minutes as she was on her way to visit a sick friend, when she informed me that she had not returned because her periods had been absolutely painless ever since. I did not see her again until this afternoon (April 29, 1892), when, as already stated, she came to engage me for her confinement, stating that she had had no pain with her periods, or at any other time, ever since. She is now five months' pregnant, and says she never felt better in her life. She attributes her having become pregnant ten years after marriage for the first time to the effects of the electricity, of course, combined with the effects of natural causes; and, although even if this be denied, this case is one more to add to over a hundred others published of women conceiving after having gone through Apostoli's treatment, contrary to the preposterous claim of Danion and others that Apostoli's method condemns the patient to sterility.

Case VII.—Miss X., a most charming young lady of 26 years and a great society favorite, came under my care a year ago, when, at the request of her physician, I performed rapid dilatation. The following is a brief outline of her case: She began to menstruate at the age of 16, and though not regular the first year became so after that, the flow generally lasting eight days. For the last four years her periods have been terrible during four days out of the eight in every month; so much so that she has had to remain in bed the whole of that time, and she hardly recovered from the prostration caused by one period before the next one was due. At the request of her physician I decided to perform rapid dilatation. At the operation I found the uterus very long and anteflexed; I took half an hour to dilate it up to one and a fourth inches and painted the canal with iodized phenol. At the first period after the operation the pain only lasted three hours instead of four days, but at the second period the pain lasted two whole days. The third period was entirely free from pain; the fourth and fifth were almost painless, but the November, December, and January periods were so painful that she had to go to bed for two whole days. I ordered dioviburnia for the three days preceding the February period, during which she only had one whole day of pain. As she was becoming discouraged, I decided to try the negative galvanic pole in the uterus; so between this and the next period I gave her four applications of 30 milliampères, without causing any pain except for a moment while the sound was passing over the internal os. The result was, that the March period caused her only two half-hours of pain. Between this and the next period she had four more applications,—the April period coming on, without her knowing it, while she was at a party. The flow this time was steady and not in gushes, and was not dark and clotted as before. I think she is cured, but I inten to give her one more application a few days before the next period is due.

Case VIII.—Mrs. G., a lady from Three Rivers, 27 years of age, married seven years, but never pregnant, consulted me on February 3, 1892. She had first menstruated at 13, always normally until after her marriage, since when the periods have become prolonged to eight days, scanty and exceedingly painful, and accompanied with the expulsion of pieces of skin after strong bearing-down cramps. I at once commenced treatment by galvanism, and gave her in all eight applications between the 3d of February and the 18th of March, with the result that there was very slight pain with the February period and absolutely none whatever with the March one. Neither were any membranes passed with the latter.

Case IX.—Mrs. B., aged 28, married six years, never pregnant, consulted me on January 22d, 1892, for dysmenorrhœa. Menstruation had begun at the age of 13 and had only been painful occasionally, always regular and lasting three days. Since marriage it has always been very painful and she has suffered from dyspareunia. When she consulted me, to quote her own words, her periods were almost arrested and it was impossible to describe the severity of her sufferings, for during the short time her periods did last she had tearing pains in the belly and was unable to endure any position. On examination the uterus was found sharply anteflexed and very sensitive to touch. Previous to connecting the battery to it the sound could not be passed, owing to the exquisite pain and spasmodic contraction of the internal os; but on connecting the negative pole to it and turning on 15 milliampères it easily glided in a distance of two and a half inches. From the 22d to the 29th of January inclusive she received four applications, 25 to 40 milliampères negative, with the result that she told me, on January 29th, that she was able to sleep all night and that the pain in the pelvis was about half as bad as before. On February 2d she informed me that she had had a period with half the usual amount of pain. During February she received five applications, with the result that her March period was absolutely free from pain, although she had a heavy feeling in the pelvis which warned her that it was coming. During March she only received two applications, but her April period came on without her knowing it or being prepared for it, while she was out walking. She stated that it was absolutely free from pain or even discomfort. I gave her two more applications and discharged her cured.

Case X.—Dysmenorrhœa of five years' standing, and having resisted all medical treatment, cured in six weeks by eight applications of negative galvanism. Mrs. G., aged 25, consulted me, February 3, 1892, on account of the intense pain she suffered at every menstrual period. She gave the following history: She had begun to menstruate at the age of 13 and continued to do so every four weeks, the flow lasting three days, until her marriage, at the age of 17. She had, however, skipped one or two periods. Up to her marriage she had never suffered any pain, but soon after that menstruation began to be exceedingly painful, so much so that she was obliged to take to her bed, and coitus was also painful. She never became pregnant, and her periods gradually grew more and more painful, lasting longer and longer until they extend to eight days. At the same time the quantity of blood lost grew less and less, and after a very severe paroxysm of pain pieces of skin or flesh would be passed. The pain was most severe at the beginning and end of her periods, compelling her to take morphine several times a day. Her bowels were confined, only moving by the aid of purgatives. On examination I found the uterus tender, but movable, and so sharply retroflexed that I was obliged to draw down the cervix in order to straighten the canal enough to admit the sound, which latter, on passing the internal os, caused severe pain. The appendages were tender, but free.

Treatment.—From the 9th of February to the 16th of March she received eight applications of the negative galvanic current to the inside of the uterus, employing the ordinary uterine sound insulated to within two and a half inches of the extremity. At the first two or three *séances* she could not endure more than 20 or 30 milliampères for five minutes, but at the last five she could bear 50 without any discomfort.

Result.—The first period after commencing treatment came on at the end of four weeks and lasted four and a half days, and the pain was so slight that she described it as nothing compared with what she was accustomed to suffer, and there were very few shreds of membrane or clots. The next period came on so easily that she was not aware of its

arrival,—finding her quite unprepared for it,—and there were no pieces of skin nor clots whatever. The pain on coitus and tenderness on digital examination had also entirely disappeared, and she was discharged cured and returned to her home in Three Rivers.

Remarks.—The fact that the passage of the sound through the internal os caused so much pain, and that pieces of skin were expelled at each period for several years, coupled with the fact that the uterus and tubes were tender on pressure, make it evident that the endometritis and salpingitis played an important part in the etiology of this case. The fact that we see many cases of retroflexion without giving rise to any symptoms would support Wylie's contention that dysmenorrhœa is always due to endometritis; in which opinion I heartily concur. If this is the case, it becomes easy to understand the marvelous effects of galvanism in dysmenorrhœa.

Case XI.—Mrs. K., aged 21, consulted me on the 5th of August, 1890. She had begun to menstruate at 14, and was regular for a couple of years, but for the past five years has only been unwell every two or three months. She has always suffered a good deal of pain, which has been much worse on the right side since marriage. She had been under the care of one of our best gynæcologists for several months, but without relief of the pain. Her periods now come on every three weeks, and last seven days,—rather profuse. I gave her one application of fine-wire faradism; at her next visit an application of a negative galvanic current of 80 milliampères for five minutes in the vagina with a carbon electrode. She was obliged to return to her home in the country a week later, and I saw no more of her until the 19th of February of this year, when she called to bring another patient to me. She stated that she had been in splendid health ever since, having become pregnant the month following her last treatment, and now being regular every month without pain.

Case XII: *Ovarian Dysmenorrhœa Cured by Six Applications of Fine-Wire Faradism.*—Miss A., aged 21, consulted me on February 27, 1889, for dysmenorrhœa. She had begun to menstruate at 16, but it had always been painful and accompanied with severe headache, and she has frequently missed a period. In addition to the above she has, since two months, a constant pain in her left side, and her periods have lately been coming on twice a month and lasting eight to ten days. She had consulted several physicians, who had all recommended removal of the ovaries. I ordered her iron and strychnine and phosphoric acid, and applied fine-wire faradism to the vagina, as near to the left ovary as possible, twice a week. On March 20th she reported that she had had a period, during which she only lost a fourth of the usual amount and with only a fourth of the usual amount of pain. She had had no headache, and her period stayed away three weeks. On April 5th she reported that she had had a period, which came on at the end of four weeks, lasted three days, and was absolutely free from pain.

Case of Painful Menstruation Cured by External Applications of Faradism.—Dr. McGinnis, of New York, reports very favorable results in such cases without having been obliged to resort to local examination. He recently reported a typical case as follows: Stated briefly, the patient was a young lady, 26 years of age, who first began menstruating at the age of 17, probably having been retarded by her close application to her studies, which terminated in that year. After that she was regular normally until a few months before he saw her, when her periods had been arrested by sudden family affliction. The next periods were accompanied with great suffering, and each one was worse than the last. One week before her next period he administered daily treatment with the faradic current as strong as she could bear it. The electrodes were on the abdomen and on the lumbar region, and each *séance* lasted eight minutes,—with the result that the next period was only slightly painful. The following month he applied electricity during the whole month,—the result being that the next period, although causing a sensation of

uneasiness, was absolutely free from pain, of which she has had no return.

Rockwell (Sajous's Annual, 1891, vol. v, page C–24) says, "I had a case in which the patient had suffered intensely from dysmenorrhœa for six or seven years and had finally resorted to extirpation of the ovaries for the relief of it. The flow had gradually diminished, but the pains had increased in severity. Under the internal application of the galvanic current ranging from 25 to 50 milliampères' strength, the paroxysms yielded rapidly and in a few months recovery was complete." He very truly adds, "If an agent like the galvanic current possesses such marked influence over so many forms of pain of obscure origin, why should not this treatment precede rather than follow operative proceedings for their relief?"

Menorrhagia.

In profuse menstruation electricity finds, perhaps, its greatest usefulness. On this point, at least, I can speak from a considerable experience. As menorrhagia is a symptom of many diseases rather than a disease of itself, we had better glance over the various causes of profuse menstrual flow, in order to see in which of them electricity in some form or other may be of benefit.

As in other disorders of menstruation menorrhagia is often due to some gross defect in the pelvic circulation. In young girls especially the bowels have been constipated for years; the appetite and digestion are consequently bad and the nutrition poor. The walls of the blood-vessels being weak and the blood thin and possessing very slight coagulating power, it naturally follows that the menstrual flow, instead of consisting of a slight oozing, becomes a veritable hæmorrhage. In such cases local treatment, as a rule, is to be deprecated; the bowels must be regulated before doing anything else, either the continuous or the interrupted current being valuable helps to this end. The quality of the blood must be improved by means of proper food, fresh air, and sunshine, while, if sufficient exercise cannot be taken, general faradization will be found to be useful.

A common cause of menorrhagia is fungous endometritis. In this disease the uterus is large and heavy and the circulation in it is bad. This is sometimes due to the fact that the organ is in a faulty position, which interferes with the circulation; or it may be that interference with the circulation has rendered the organ large and heavy and caused it to fall backward and downward in the pelvis; or it may be the result of subinvolution after a miscarriage, or a septic confinement at term with or without a laceration of the cervix. In cases of menorrhagia from these causes I have had most gratifying results with the continuous current, the positive pole in the uterus. We can be almost certain in every case that the uterus will return to its normal depth and size after from five to

twenty applications. The reader who wishes to refer to the Carlet thesis on "Electrical Treatment of Fibroids" will find a great number of cases reported not only of fibroids, but also of endometritis and enlargement of the uterus, in which the organ was restored to its normal size. I have also reported a great many cases of displacement due to enlargement of the uterus, which were cured by reducing the weight of the uterus by means of the continuous current and afterward strengthening the supports by the aid of the coarse interrupted current. Incidentally three of the patients who were suffering from menorrhagia were also cured of this symptom. When the enlargement is due to subinvolution the interrupted current acts very well by setting up powerful contractions of the uterine muscle, thereby cutting off the too-great supply of blood to the sinuses and causing fatty degeneration and absorption of the superfluous muscular tissue. When the enlargement is due to areolar hyperplasia the interrupted current is useless, as only the continuous current will cause absorption of fibrous tissue.

By most writers fibroid tumors are considered among the principal causes of menorrhagia, but in my opinion they are merely a coincidence with the fungous endometritis, both being due to the same cause, namely, obstructed circulation in the uterus. I have been led to take up this view from the consideration of the histories of a large number of cases of fibroid tumor which occurred either in nulliparous or in parous women. In every one of the nulliparæ there had been a long previous history of constipation, which, I need hardly point out, obstructs the return of blood both by the uterine and by the ovarian veins. In many of these nulliparæ there was, in addition, a history of tight lacing, jamming the liver against the inferior vena cava, which receives all the blood from the uterus and ovaries. Nearly all had led a sedentary life. Among the women who had borne children there was a history of lacerated cervix, subinvolution, retroversion, and prolapsus, causing a twisting of the broad ligaments and direct mechanical pressure by the fundus on the internal iliac veins and on the rectum, causing constipation.

My theory concerning the production of fibroids is that, the veins of the uterus being obstructed, white blood-corpuscles begin to pass through the walls of the blood-vessels and after a time become organized into fibrous tissue. This nodule of hard tissue, in turn, still further obstructs the circulation, and more plastic lymph is exuded around it, thus increasing both the cause and effect. When the lymph-channels are at the same time blocked by pressure the lymph-spaces in the uterus near the tumor become distended by lymph, and thus we have the formation of fibro-cystic tumors. This view is supported by the microscopical examination of this fluid, which proves that it contains no traces of broken-down tissue, as would be the case if it were due to the disintegration of the fibrous structure. I have, therefore, every reason to believe that both the fibrous and the fibro-cystic tumors are due entirely

to obstruction of the venous and lymphatic circulation. I also maintain that the fungous endometritis which so often accompanies a fibroid is due to the same cause. In hundreds of cases of profuse menstruation I have almost invariably seen the flow diminish merely by improving the pelvic circulation, and very often with no other treatment than the cure of the constipation. In these cases the obstruction had not been severe nor prolonged enough to cause exudation through the walls of the blood-vessels, but it had been bad enough to cause a fungoid or spongy condition of the endometrium.

Whatever may be the cause of the obstructed circulation the condition is generally the same. The mucous membrane is thick and velvety, sometimes lying in folds, and the very close capillaries which supply it bleed profusely on the slightest injury. So weak are the walls of the blood-vessels in some of these cases that I have seen the introduction of a sound or even of a soft bougie followed by the appearance of a stream of blood pouring from the os, although the instrument was handled in the gentlest possible manner.

This is the condition of the mucous membrane which is generally present in cases of fibroids, which gives to the uterine myomata their most characteristic symptom of hæmorrhage. It is not within the province of my section of this work to treat of uterine tumors, yet, having had considerable experience with them, I have come to the conclusion, as already stated, that it is not the tumor, but rather the condition of fungous endometritis which so often accompanies it, as well as the increased area from which the hæmorrhage takes place when the cavity of the uterus is thus enlarged, which are the real causes of the bleeding.

If now the spongy and exceedingly vascular endometrium be removed, instead of varicose veins, which easily break and remain open, we shall have, on the contrary, small arteries which, when cut across or otherwise destroyed, immediately contract and close up. As has long been known and advocated by many, the cleaning out of the uterus with a sharp curette has been found a useful temporary expedient for the arrest of hæmorrhage; but to be effective at all it is most essential that the curetting be followed by the application of a caustic which will close up the open ends of the blood-vessels. The intra-uterine application of the positive pole of the continuous galvanic current, if of sufficient strength to cauterize, will produce precisely this effect. Moreover, the mere fact of passing a strong current through the electrode is sufficient to guarantee the asepticity of the proceeding, thereby rendering it perfectly harmless.

One thing which the chemical galvano-caustic curetting (if we may so call it) will do more than the removal of the hypertrophied mucous membrane by the sharp curette is, that the interpolar action of the current exerts a powerful influence upon the trophic nerves. Of the actual existence of this interpolar action I have not the slightest doubt, for I

have witnessed it in one case where circumstances placed the proof beyond suspicion. This was the case, which I have already reported, of a patient who was sent to me by Dr. Brennan, of this city, on account of terrific hæmorrhage, which on several occasions had nearly ended her life. She was the subject of a large submucous fibroid the size of a fœtal head, which had been squeezed into the uterine cavity and afterward expelled into the vagina in the form of a polypus, completely filling the pelvis, leaving barely room to introduce the finger beside it, and having a large and broad pedicle running up the uterine wall. A leading surgeon had seen her previously, and determined to remove it with the écraseur. On the morning of the operation, however, the patient was so exhausted that it was found impossible to administer an anæsthetic, without which he would not venture to undertake the operation, which was therefore postponed. After that she had still another frightful hæmorrhage, and a few days after that she was carried from a sleigh into my office by her husband and her family physician. It was some time—perhaps an hour—before I could place her on my examining-table, when I found the condition of things as above stated.

The case being so favorable for galvano-puncture, I placed the negative clay electrode on the abdomen and plunged the positive platinum trocar into the centre of the mass to a distance of a little more than a fourth of an inch, and turned the continuous current on until I had reached 150 milliampères, which the patient bore without flinching, and beyond which I could have easily gone. There was decided scarring around the trocar, which was held firmly by the coagulation of liquids, but which was removed without difficulty by the aid of a gentle jerk.

Four or five *séances* in all, of from five to ten minutes' duration each, were given, at intervals of two or three days, with the most marvelous results. Her next period was only a little more profuse than the normal amount, and, instead of lasting half a month, only lasted four or five days; but the most remarkable effect of all was the cessation, from the very first application, of the profuse and exhausting leucorrhœa which poured from the surface of the polypus. This, as I have said, was completely stopped, and although I have not seen nor heard of the case for a year or two the patient was, when I saw her last, in apparently robust health.

Now, in this case there was no cauterization of the bleeding mucous membrane covering the polypus, which no doubt furnished a large part of the hæmorrhage, as well as most of the profuse watery discharge, which, moreover, is a frequent accompaniment of submucous fibroids; so that any benefit which was apparent in this case was certainly due to the action of the continuous current on the tumor as a whole or as a part of the uterus, and could have been due to nothing else than the interpolar action of the current.

Although the interpolar action is too important to be lost sight

of, and can be made use of in cases of hæmorrhage in which it is impossible to introduce the intra-uterine electrode, yet the local, chemical, cauterizing action is much more effective and rapid in its action.

It might be well for me to mention here the *modus operandi* in which the galvanic current arrests hæmorrhage, as was first pointed out by Apostoli, and as I described in my paper before the Ninth International Congress (" Transactions," vol. ii, p. 665). When the two poles of a galvanic current are immersed in water the latter is decomposed, the oxygen bubbling up from the positive pole and the hydrogen from the negative. Now, if we replace the water by a saline solution the latter will be decomposed, the acid coming to the positive pole and the base to the negative. This same chemical decomposition takes place when these respective poles are placed in contact with the saline solution of tissue, and we have all the effects of an acid or alkaline caustic, according to the pole introduced. In employing the galvanic current in sufficiently large doses to be effective in going through the fibroid, it is necessary that the milliampèrage be very great; so much so that with a small electrode so much action takes place in passing through the skin that the latter is even burned. Apostoli has overcome that difficulty by substituting a very large cake of moist potters' clay, which is placed on the abdomen of the patient and which is used as a negative electrode. As the acid developed by the positive pole will very soon eat into the metal of the intra-uterine electrode if made of silver, steel, or copper, Apostoli employs an electrode of platinum; or, in case the uterine canal is very large, in order to save the expense of a correspondingly thick platinum electrode, he has found carbon tips equally effective. I have had a number of these made from the little pieces of carbon thrown away from the electric arc-lamps, and which can be turned by any machinist into the desired size and shape. I have latterly advocated the employment of pure tin electrodes, which are only slightly oxidized by the passage of the current, and, being so cheap, can be thrown away when damaged. I have still later advocated the use of electrodes of pure zinc instead of carbon, made of various sizes, all to screw on to the same insulated stem, for the following reason: Chloride of zinc has long been known to be the most effective material for applying to the interior of a bleeding uterus, but its application is difficult and sometimes dangerous, owing to the impossibility of limiting its effects; but by applying the zinc electrode to the interior of the uterus the saline solution of the tissues is decomposed and the hydrochloric acid of the chlorides attacks the zinc, forming chloride of zinc on the surface of the electrode, and by moving this around slightly in the uterine cavity the latter can be thoroughly coated with a minute layer of chloride of zinc. I have not used this long enough to speak very decidedly about it, but I would recommend this material for future experimentation.

Galvanism has recently been recommended for the cure of cancer of

the uterus; and from the fact that the disease is in the beginning a distinctly local one, due to the presence of a microbe, and seeing that a powerful galvanic current has been proved to be distinctly germicidal, there may be some ground for the hope that electricity will yet prove effective against this terrible enemy of women.

Cancer of the uterus generally commences in one of two ways: either at the cervix, where it is the seat of a laceration which allows ectropion or exposure of the delicate mucous membrane of the cervical canal, which is constantly subjected to various forms of violence and irritation, or the disease begins in the mucous membrane of the body of the uterus or of the cervical canal. In the former case it generally happens to parous women, while in the latter it may occur in those who have never had children.

Whatever may have been the experience of others, I must maintain that in my experience a neglected and everted cervix has been the cause of the majority of the cases which have come under my notice, while the remainder, with one or two exceptions, have been the result or, apparently, the second stage of fungous endometritis or proliferation of the glandular structure of the mucosa.

It has also been my experience that it was almost impossible to state at what moment any given case of cancer of the uterus was not cancer, but merely proliferating endometritis. I have also frequently heard it stated by operating gynæcologists that they could place but little reliance upon the microscopical appearance of the mucous membrane removed by diagnostic curetting, as some cases which gave a negative result by this means afterward became undoubted cases of cancer, while in other cases where examination of the mucous membrane removed led to the strong suspicion of malignant disease, the patient having refused operation, remained free from the disease for many years after.

When there is a severe lacerated cervix, no time should be lost in repairing it. The general opinion of gynæcologists at the present day is that it is advisable, in all cases where the symptoms lead to the suspicion of cancer, to remove the cervical portion by high amputation, or else to remove the entire uterus. Certainly the latter plan is the most effective, as well as the most radical, but in the majority of cases it is impossible to induce the patient to consent to so serious an operation; which, moreover, is rendered still more terrible by the feeling generally entertained by most women that the removal of that organ is a serious mutilation, and that without it it is impossible for a woman to live. In such cases we must fall back upon the least-terrible operation, especially if it afford a fairly-good chance of indefinite immunity from the disease.

I remember one such case,—a Mrs. N., who came to me about three years ago, having been given up by her physician, on account of a hæmorrhage which had lasted without intermission for over a year. She was poor, exceedingly weak from loss of blood, and entirely opposed to an

operation. She was about 40 years of age, and the subject of a severe laceration of the cervix, which had never been repaired. At the time I was experimenting with the hæmostatic action of the positive galvanic current, and thought her a suitable case on which to test it. After three or four applications of the platinum sound, which I moved freely about in the uterus, the hæmorrhage entirely ceased; and had not returned at the end of a year, since which time I have completely lost sight of her.

I only mention this case as one illustrating the almost infallible power of the positive galvanic current to arrest the severest forms of hæmorrhage. I do not pretend, or at least I do not wish to maintain, that it is able to cure advanced cases of cancer. Although, as I have already said, these growths do not come within the scope of my article, I may mention that the hopes which I had entertained, as a result of my success in this one case, were doomed to disappointment in a subsequent case, in which the disease was very far advanced:—

A Mrs. K. was sent to me by Dr. Cowley, of Granby. She had already been sent away from the General Hospital on account of the hopelessness of her case. The uterus was enormously enlarged, the broad ligaments were swollen to many times their natural size with the cancerous deposit, and even the vagina was invaded in its upper third; but, worst of all, there was a large epithelial growth at the umbilicus, which was like a mushroom, looking like raw, granulated tissue. This proved to be quite a barrier to the effective use of the current; however, by placing the clay electrode on the sacrum, attaching thereto the negative pole, and introducing a large carbon electrode attached to the positive pole into the distended uterine cavity, I was able to give her some doses of 50 to 75 milliampères. The patient declared her general condition was improved; but, in my opinion, the disease was not arrested, and the patient died in the Western Hospital, some weeks after cessation of treatment, by the extension of the disease to the peritoneum.

In commencing cancer, if the application of electricity does good, it must do so in one of three ways: Either because cancer being due to the growth of a microbe, which ultimately blocks up the blood-vessels and causes necrosis, strong electrical currents, in virtue of their microbicidal action, kill the germs and arrest the disease; or, second, because the well-known tonic action of electricity on the trophic nerves improves the nutrition of the tissues, on which the disease can only spread because the vitality of the tissues is at a low degree,—we know that cancer nearly always attacks localities where constant irritation has been followed by the production of cicatricial tissue of low formation, as in the cicatrix of a lacerated cervix, or of a clay-pipe-smoker's lip, or a cigar-smoker's throat, or of an ulcerated rectum; or, third, because it destroys the microbe-laden tissues in the same way that the actual cautery does.

As electrical treatment can be employed without an anæsthetic, it has that advantage over the actual cautery. Dr. Inglis Parsons, of London, claims to have had remarkable success with the continuous current the direction of which is reversed more or less rapidly. While the subject is well worthy of consideration, my own experience is too limited to make any very strong claim beyond that I have arrested a

profuse menorrhagia in a woman who had every appearance of having cancer of the cervix. I would refer the reader to the chapter on "Treatment of Cancer of the Uterus by Electricity," in another part of this work.

One of the strongest advocates of the hæmostatic action of the positive galvanic current was Dr. W. S. Playfair, the well-known author of the celebrated standard text-book on midwifery. He says that the things which appear to him best settled are the facts of the hæmostatic action of the positive pole, which, even if it act as a cautery, does its work far better than any other cautery known or than any remedy adapted for the purpose. The latter measures so often fail that removal of the uterus or uterine appendages becomes frequently necessary. In only one case out of eighteen of metrorrhagia had the measure proved inefficacious, and in that the case and surroundings were very unfavorable. The others all gave good results, and yet many of them had already submitted to other modes of treatment, and without avail. Four of his cases had given absolutely good results:—

The first was a case of several years' duration, attended with severe uterine pain and menorrhagia, for which all methods of treatment had previously been exhausted without relief. There was a fibroid in front of the cervix the size of a very large orange. The sound passed three and one-half inches into the dilated cavity. The interval between the periods was from seven to ten days, and the periods lasted ten to twelve days, while from twenty-five to forty diapers were used every day. Fourteen applications of the positive electrode were made, generally of 200 milliampères. The periods steadily lessened in quantity and the intervals increased in length. The last interval, at the time of reporting, was twenty days, and the last period only lasted four days, being quite normal in quantity. She was enabled to resume her duties as a governess, which she had been compelled to abandon.

The second case had been under Playfair's observation for several years. The hæmorrhages were very frequent and often amounted to severe flooding. The patient was blanched, very anæmic, and a confirmed invalid. After six applications she was compelled to leave for the tropics. After ten months she wrote stating that the periods had continued to become less and less.

The third case had suffered many years from hæmorrhages, which increased after her marriage, a year ago. She often had to be plugged, and once her uterus was dilated and examined under an anæsthetic. No improvement followed. On arrival at the King's Hospital she was blanched and alarmingly prostrated, having to be plugged in order that she might be removed there. On removing the plugs the hæmorrhage recommenced at once, but ceased on using a current of 80 milliampères. For some weeks several applications were made of 200 milliampères, during which time there was no recurrence. Then she insisted on leaving, promising to return if the bleeding came on again, since which she has not had to return.

The fourth case, 54 years of age, always having menstruated profusely, and grown much worse for a year or more. She had been losing blood continually, with only a day or two's intermission, for the last seven months. Applications were given in March. Twelve applications of 200 milliampères were made and the hæmorrhage soon entirely ceased. On the 28th of June she wrote to say she had had no return of the bleeding.

Playfair challenged any one to produce four such cases treated by any other means than hysterectomy or removal of the uterine appendages in which anything like as good results followed any other form of treatment.

At the Glasgow Obstetrical Society Skene Keith produced six cases of profuse menorrhagia, lasting from several months to many years, and all accompanied with most profound anæmia, which were all cured by the electrical treatment. As to the risk attending this treatment, he had made thirteen hundred and fifty applications and had only one accident.

Dr. J. T. Everett reported that he had had 75 per cent. of cures with intra-uterine applications of the galvanic current.

Dr. Taylor, of England, reports the following interesting case :—

Mrs. S., aged 46, a widow, had been suffering for one and a half years from hæmorrhage, lasting seven days and coming on every two weeks. Twenty-eight applications of the positive intra-uterine galvanic current, extending over a period of ten months, or rather less than three applications a month, the strength of the current being 200 milliampères, was followed, at the end of that time, by menstruation coming on regularly without pain and normal in amount.

Even Dr. Franklin Townsend, who is an opponent of this method of treatment, in reporting the result in seventeen cases, concludes that the hæmorrhage seemed to be controlled in all those cases in which it appeared to be profuse.

Engelmann points out that all observers, even though unfavorably inclined, have found that the influence of electricity on hæmorrhages is, with the exception of a very few cases, an exceedingly favorable one.

The limited space at my disposal will prevent me from reporting all of the cases which came under my own care and were cured by electricity. But I cannot allow the opportunity to pass without reporting a few of them :—

Mrs. P., nullipara, aged about 30 years, consulted me in July, 1889. When I first saw her she was in bed, with the foot of the bed raised, and she was thoroughly exsanguinated, fainting away on the slightest exertion. She had been having prolonged and profuse periods for several years, and had taken ergot steadily for many months without avail. A few weeks before my seeing her she had been so near dying from hæmorrhage one night that a general practitioner and a gynæcologist had been called in the middle of the night, and only succeeded in arresting the flow by tamponing the vagina and packing her in ice. After taking her case in hand I was obliged to tampon her with styptic and antiseptic tampons every day for a week before I could arrest the flow, and after that it took another week to strengthen her up enough to enable her to drive to my office. Dr. Marcy, of Boston, happened to be paying me a visit at the time, and I asked him to examine her with me,—which he did, and we found a large, submucous, fibroid tumor. In order to estimate the depth of the uterus, I introduced a soft gum-elastic bougie a distance of over six inches, and, although it was introduced without the slightest difficulty or force, the blood poured out of the uterus on to the floor before I had time to catch it. The positive platinum electrode was then introduced up to the fundus and the clay pad, connected with the negative pole of the battery, was placed on the abdomen. At this *séance* she received 75 milliampères during five minutes, which was so well borne that at the next visit I increased the dose to 125 milliampères. On August 10th I gave her 150 positive for six minutes, when she told me that she was feeling much better in every way. On August 13th she had a dose of 175, and on August 15th she easily bore a dose of 190 milliampères positive. This patient received in all about twenty applications, with the following result : At the first application the blood in the uterus was firmly coagulated around the platinum sound so that it came out quite dry, and the bleeding stopped within a minute of turning on the current, and did

not return except on first introducing the sound at the next three applications. After that there was no more bleeding on introducing the sound, showing that the spongy, fungous endometrium had been dried up by the positive galvanic applications. The next period after commencing this treatment was less than a half so profuse as usual. At the end of the treatment the menstrual period had come down to three or four days, and has never since been profuse, although she has been doing all her own work for several years. I had occasion to send her a message to come and see me last September (1891), when I found her lips and cheeks quite rosy, and she assured me that she had been free from menorrhagia ever since. I have already reported her among my cases of fibroids symptomatically cured, the tumor also being reduced about a third in size.

Another case, which I have also reported as a cure, was a Mrs. X., the wife of a leading physician in this city, who came under my care for menorrhagia. On examination I found that this was due to fungous endometritis, associated with a fibroid in the posterior wall of the uterus, and retroversion, all being probably caused by a laceration of the cervix. The perineum was also lacerated through the sphincter ani, so that she was unable to control her bowels if they were at all liquid. She had already been curetted and iodine had been applied to the interior of the uterus, but without arresting the hæmorrhage for more than a few months. The bleeding at every period had now become so profuse that she was obliged to make all her preparations to remain in bed for a whole week, and sometimes ten days, out of every month, and even with that precaution she used to become so weak that she would faint away in bed, and had to have the foot of the bed raised. She received in all about a dozen applications of positive intra-uterine galvanism, sometimes with the platinum electrode and sometimes with the carbon tips. She was exceedingly nervous and sensitive, and could seldom endure so strong a dose as 100 milliampères. Nevertheless, the bleeding was so quickly controlled that she was never obliged to remain in bed since, and her periods are now very little more profuse than normal. I have since repaired the cervix and perineum, and she is improving steadily in health all the time.

There are many similar cases in my note-books, but the result was generally the same. In a few cases the patients left off treatment after two or three applications, because they felt so much better that they considered themselves cured. In some of these the benefit was only in proportion, and in some of them there were relapses, but they had only to return for a few more treatments in order to have the bleeding permanently cured. As regards the permanency of cure, I attribute this partly to the permanent cure of the constipation, which, as I have already said, I believe to be an important factor in the causation of menorrhagia. In a few cases, after having treated the patient with electricity, I have subsequently resorted to the knife. As these may be classed as failures, a short reference to them may prove of interest.

Miss I., aged 35, was sent to me by Dr. Chown, of Winnipeg. She had been engaged in a sedentary occupation for seventeen years, since which time she had suffered from dysmenorrhœa until four years previous to coming under my care, when the pain ceased and flooding began. This became so severe that nothing would arrest it except tampons, until she underwent treatment by Apostoli's method, at Minneapolis. This diminished the flow, but owing to the tortuous condition of the uterine canal the doctor there was unable to introduce the sound more than an inch and a half. On examining her I found a hard, round, interstitial, solid fibroid in the body of the uterus, the size of a full-term fœtal head. I was unable to introduce the platinum sound farther than the Minneapolis doctor did, but, finding that a gum bougie would enter in a tortuous manner to a distance of five inches, I covered the bougie with closely-wound aluminium wire, thus making a flexible positive pole, with which I gave her nearly fifty applications. Owing to a concomitant salpingitis I was unable to give her high doses, and even moderate ones necessitated a little anæsthesia. In a little

less than six months her period was reduced from eight days to three days, and I discharged her, as I hoped, cured. She then went to the sea-side on a visit and returned, in April of this year, looking stout and rosy and feeling well in every way. She asked me if she could be sure that the bleeding would not return after she got home? I replied that neither electricity nor the removal of the appendages was certain to prevent the return of the flowing, the only thing that could be absolutely certain to do so being the removal of the tumor with the uterus, appendages and all, by abdominal incision. She urgently demanded this operation, which I performed on April 13th, assisted by Drs. Armstrong, Spendlove, and Mitchell, at Strong's Hospital. I screwed a corkscrew into the tumor and thus lifted it out of the incision, and then threw a very tough wire around it, as low down as possible without taking in the bladder, and I then pushed two pins through the tumor just above the wire. The tumor was then cut off and the tubes and ovaries with it. Some have claimed that Apostoli's method causes pyosalpinx, pelvic peritonitis, and many other serious conditions; but it did not do so in this case after fifty applications, for, on examining the tubes and ovaries, nothing was to be seen but a little congestion. Owing to shrinking of the stump I was obliged, a few hours after the operation, to tighten up the wire loop in order to control the oozing. Next day it started again twice, by which time the end of the screw was reached. I then placed a rubber catheter-tube around it under the pins, without avail, but on placing another instrument with a stout linen cord on it I had no further trouble. About six ounces of blood was thus lost up to the thirteenth day. The temperature had never gone over 100° F., but on the fourteenth and fifteenth days it touched 102° and 101° F., respectively. The patient made an uninterrupted recovery, leaving the hospital at the end of five and a half weeks, and returning to Winnipeg in the seventh week. She has since been heard from, and is enjoying excellent health.

Although this case was finally operated upon, I can hardly call it a failure of electricity. If the patient had been living within a hundred miles of Montreal she would probably not have been operated upon. As will be seen by the reports of the few cases where bleeding has returned, four or five further applications have permanently arrested it; so that the operation was performed not because electricity had failed to reduce the bleeding and other symptoms, which it did, but because I could not guarantee that those results would be permanent by any treatment or operation short of total extirpation. As you are aware, there are many cases on record of failure of removal of the appendages to arrest menorrhagia.[1] One such case as this should forever silence those who are operating on a bad case of fibroid adherent to surrounding viscera, and, learning that the patient has been submitted to a few applications of electricity, at once accuse the latter of having been the cause of all the trouble. If electricity can cause adhesions at all, it must do so in every case; but in this case there was not a sign of an adhesion, although the patient received nearly fifty applications during nearly six months.

Miss L., aged 45, came to me on September 26, 1890, suffering from profuse menstruation and severe pains in lower abdomen, and difficulty in passing water and emptying the bowels. She had had profuse periods since 12 years, passing large quantities of clots. Two years ago had profuse discharge of pus, which had returned several times since. On examination I found a hard submucous tumor the size of a full-term fœtal head. Sound entered six and a half inches forward and to left. Os very small. From September 26th to December 26th I gave her about twenty applications of the continuous positive galvanic current, strength of 150 milliampères, with the result that she improved very much in

[1] While writing this Dr. Gardner showed a uterus which he had removed one year after the failure of removal of the appendages to cure the hæmorrhage.

general health, the menorrhagia and all the other symptoms being removed, and she was able to resume her work as a tailoress. I did not see her again for two or three months, when she sent for me, and I found the os uteri open to the size of a silver dollar and a free discharge of fetid, dark blood. I could feel a large tumor presenting, around which I could freely sweep my finger. As her temperature was rising, I decided to remove the uterus by abdominal section, and went the next day prepared to do so; but she objected to that operation, and urged me to do something less serious. I unfortunately yielded to her request, and tried to put a snare on the tumor and remove it per vaginam. But the tumor was so necrosed that no instrument would hold in it, and I finally scooped it out with my fingers right up to the fundus. In this I was ably assisted by Dr. Spendlove. There was free bleeding while this was being done, but it was immediately arrested by intra-uterine injections of hot water. I then packed the uterus full of boracic gauze and filled the vagina with boracic acid. After the operation I noticed a tiny laceration at the fourchette, which I thought trivial at the time, but which was destined later on to be of some importance. I took a piece of the tumor which I had removed to Dr. Johnson, who declared it round-celled sarcoma,—a conclusion which I could easily verify on examining the section under the microscope. I at once urged the patient to allow me to remove the entire uterus, but she refused, and I was discharged.

I did not see her again, but have been informed by Dr. Hingston that she applied to him at the Hôtel-Dieu two months later for relief from a cauliflower growth, which had sprung from the tiny cleft in the fourchette. He also informed me that the uterus had returned to its normal size, and that there was no sign of a tumor about it. Shall I put this case down as a failure of electricity to do anything? Hardly; for it enabled her to return to work and relieved all her symptoms. But if the case is put down as a failure, I think it only fair to place the fault to my charge for making an error of diagnosis. If I had known that this was a case of sarcoma from the beginning, I would have treated it by extirpation of the uterus by abdominal section. Not only does the electrical treatment deserve no blame in this case, but rather it should have the credit of relieving the patient's menorrhagia and other symptoms for a considerable time.

Miss B., aged 26, was another case which illustrates the impossibility of the electrical treatment causing the adhesions so often placed to its credit by the electrophobic operators. She came under my care in July, 1889, for menorrhagia and a fibroid tumor of the uterus. After about fifty applications, extending over nearly four months, she was thought to be symptomatically cured,—the pressure symptoms being all relieved and the profuse periods being reduced to normal quantity. I was about to allow her to return home when a period came on before the time and lasted thirteen days. This was enough to make me consider the case a complete failure of the electrical treatment, and I accordingly urged her to have abdominal hysterectomy performed; which was done by Dr. Trenholme, with my assistance. On raising the tumor out of the abdomen it was found to be perfectly free from adhesion except at a spot, the size of a five-cent piece, to the right of the uterus, where it rubbed against the brim of the pelvis, but altogether out of the road of the current. In fact, she had complained of pain at that spot long before she had ever been treated with electricity. On examining the extirpated uterus I found that the point of the solid platinum sound had eaten a little hole, about a sixteenth of an inch thick, into the wall of the uterus, and had opened a small vein, which had given rise to the bleeding; the endometrium was otherwise healthy. Had I known of or suspected the possibility of this accident I would not have advised abdominal hysterectomy, as the patient had been cured of all her symptoms except the one depending on this accident. This, however, will not occur again, for whenever I intend to employ high currents I take care to cover the end of the sound with sealing-wax;

or, better still, I employ a flexible bougie, covered with aluminium or platinum wire, the end of which, being of gum, can do no harm.

Another bad case of menorrhagia was a Miss A., a very intelligent and clever girl employed in an office. She was obliged to take a much smaller salary than she was otherwise worth, because for several days of every month her periods were so profuse that she dared not leave her bed; and for several other days such large clots would come away from her while she was at the office that she was obliged to stand on a newspaper and allow them to fall to the floor. When she came under my care she had exhausted the resources of drugs, especially of ergot, and was as white as wax. I treated her with positive intra-uterine galvanizations during several months, giving in all over sixty applications, of an average strength of 125 milliampères, with the result that the blood soon ceased to come away in clots, and then the duration of the periods gradually came down from eight to four days. All her other symptoms being improved, she was allowed to depart, and took a situation in Scranton, Pa. I saw her again about a year later, and found her with red cheeks and almost the picture of health. She informed me that the menorrhagia had steadily diminished ever since, so that she no longer felt very much inconvenience from it. She has now been married for about six months.

But, as I have already said, there are so many cases recorded of menorrhagia having been cured by intra-uterine galvanizations that they alone would fill many volumes. I shall not, therefore, take up any more space in relating others from my own note-books. That this treatment will cure menorrhagia almost with certainty is one of the best-established facts in therapeutics.

Menopause.

When the time comes for the cessation of the regular monthly tide toward the pelvic organs many women are liable to suffer from a collection of symptoms which may be grouped under the heading of "disorders of the menopause." By far the most important of these are what may be called head-troubles, or, at any rate, troubles of the nervous system. It seems to take from a few months to a year or more for the organism to accustom itself to the new condition of things, and during that time the woman suffers more or less from fullness of the head, hot and cold flashes, etc.,—all indicating a temporary derangement of the great vaso-motor nerve. After a time the circulation becomes reorganized or re-distributed, and the patient returns to good health. I have generally been able to make these women comfortable during that uncomfortable time by means of a liberal use of the bromides for the purpose of controlling the quantity of blood in the brain, and of salines to increase the quantity of blood flowing toward and in the intestines. But wishing to ascertain the effect of the electrical current for this purpose, I tried it on a number of cases, with the following result: Bipolar intra-uterine faradization with a medium wire causes a flow of nervous energy, and sometimes of blood, which make a very fair substitute for the menstrual flow. Secondly, intra-uterine negative galvanizations cause a flow of blood toward the uterus, which has in some cases afforded great relief to these patients. In women who reach the menopause without having been married intra-uterine or intra-vaginal applications are generally refused.

In such cases general faradization or local galvanization will generally be found beneficial. By applying the electrodes of the continuous current to each side of the thyroid gland, so as to stimulate the great sympathetic nerves, the calibre of the cerebral blood-vessels can be very much diminished, and very much less blood will therefore flow to the head. In some cases of premature menopause the menses can undoubtedly be made to return by means of the same treatment, with negative galvanism, that I have already indicated in speaking of amenorrhœa and dysmenorrhœa.

In conclusion, I may say that, far from abandoning the treatment of the disorders of menstruation, my experience with it grows more favorable the more I use it, and I shall, therefore, employ it much oftener in the future than I have in the past.

TREATMENT OF DISEASES OF THE FEMALE URETHRA BY ELECTRICITY.

By FRANKLIN H. MARTIN, M.D.,

CHICAGO.

Difficulties of the female urethra amenable to any form of electrical treatment may be divided into surgical and non-surgical. Surgical diseases will include those cases in which the galvano-cautery as a surgical measure may be found of value. This excludes, of course, all surgery of a plastic nature.

Galvano-cautery of the Urethra.

Urethral caruncles are often very easily removed by the galvano-cautery. If the little tumor have a contracted base a small platinum loop may be thrown over it while it is exposed, and as the loop is tightened the current is switched on and the caruncle removed. There is no hæmorrhage and little pain. If the growth is not sufficiently pedunculated to admit of the above measures, the whole mass can be dissipated by attacking it with a blunt-pointed electrode on its surface, or with a knife electrode at its base.

Venereal ulcers of the meatus or urethra are easily and conveniently cauterized with the galvano-cautery.

Urethral ulcers of a non-venereal type are frequently attacked with the galvano-cautery, either through an endoscope or urethral speculum.

Urethral polypi are easily and safely removed by the écraseur-snare electrode of the galvano-cautery machine.

Strictures of the Urethra.

Electrolysis for stricture of the urethra may be considered under the head of a surgical procedure.

The female urethra may be the seat of a cicatricial stricture the result of traumatism, or of an infiltrated stricture the result of urethritis. Electrolysis for this difficulty possesses advantages over gradual or rapid dilatation or cutting. The results from electricity are usually permanent, while from the three procedures mentioned above there are frequent relapses.

I employ for the active urethral electrode in this work a small urethral staff composed of copper wire insulated with a stiff covering of hard rubber, upon the end of which can be secured, by means of a screw, bulbous metal points of any size required. By heating the staff in warm water it may be molded into any required curve. For an external or

indifferent electrode a large sponge, membranous, or clay electrode may be used.

Method.—A bulb is selected which is a trifle larger than the first stricture. It is screwed on to the staff, and the staff is attached to the negative pole of a galvanic battery. The current is completed by the application of the positive electrode, in the form of a sponge, on the thigh of the patient. While the active electrode is passed into the urethra and the bulbous point is held firmly in the stricture the current is gradually turned on until 10 to 12 milliampères are reached. By firm, gradual pressure the electrode will slowly dissolve its way through the stricture. When it has traversed the stricture, or strictures, into the bladder it is cautiously and slowly withdrawn until it has repassed them, and then the current is switched off. At the next treatment, which should be in about three days, a bulb two sizes larger should be employed. The application should be repeated at intervals of three days with larger and larger electrodes until the difficulty is completely eradicated. A current of sufficient strength to cause cauterization should never be employed for strictures. When a sensation of severe pain follows the treatment the current has been too strong.

Functional Disturbances of the Urethra.

Functional disturbances of the urethra which are dependent in a large degree upon remote causes, and which may be influenced beneficially by one or more forms of medical electricity, are so intimately connected with the bladder that it is difficult often to separate them.

Incontinence of urine from an atonic condition of the urethral sphincter and the sphincter of the neck of the bladder may frequently be relieved by the powerful tonic effect of a local application of the faradic current.

It may be applied by means of a bipolar urethral electrode with the active points corresponding with the two sphincters, or it may be applied by means of a simple urethral bulbous electrode as the active pole, and an indifferent pole, or sponge electrode, placed over the bladder on the skin. When the effort is directed to increasing the muscular tone the coarse-wire secondary coil should be employed. The sittings should be about five minutes, and may be given as often as every day.

Nocturnal incontinence of urine in children, or when it occasionally occurs in adults, may often be greatly benefited or permanently relieved by means of the systematic application of the tonic faradization through the pelvis, or, when the case is aggravated, by direct application to the urethra. In children one pole may be placed over the perineum, in the form of the standard electrode, and the other above the symphysis over the bladder. A current of considerable strength from the coarse wire, with interruptions of about 120 a minute, should be employed for from fifteen to twenty minutes every day until the symptom has quite disap-

peared, and then every day following the night in which the symptom re-appears.

Neuralgia of the urethra is a painful symptom that may be promptly relieved by means of the galvanic current. One electrode in the vagina and a large sponge electrode, representing the opposite pole, placed over the bladder, with a 10- to 15- milliampère current for a five-minute sitting, is a convenient method of applying the current for this trouble.

Bladder.

Neuroses of the Female Bladder.—Anomalies of the badder, according to Winckel, without structural disease or abnormality of its contents, which thus have their seat in the nervous apparatus of the organ, are designated neuroses. They include spasm, paresis, and paralysis of the bladder. To these may be added bladder pains of locomotor ataxy and instability of the bladder due to chorea.

Bladder cramps, neuralgia, or cystospasms, according to Winckel, may be caused by great emotional disturbances, onanism, excessive coition, and colds, especially at the menstrual period, from sitting on the damp, cold ground, as well as getting the feet wet. According to the same author, only when the urine, being entirely normal, the urethra healthy, no anomaly of blood-supply, and the texture of the walls of the bladder can be found by touch or sight, and when also, after dilatation of the urethra with specula, to which patients in obstinate cases readily submit, no local, visible, or palpable anomaly can be detected; only when, after illumination of the interior wall of the bladder by Rutenberg's mirror, no disease is found; only then can primary spasm of the bladder be properly spoken of.

When these various symptoms are met with, remote causes should be removed and appropriate medication applied. Our province here is to point out in what manner electricity may be employed as an important remedy or an adjuvant.

In cystospasm or neuralgia of the bladder, faradization, by means of the fine-wire secondary coil, has frequently a prompt and most gratifying effect. A urethral electrode with a bulbous metal point inserted into the bladder as the active pole in aggravated cases, with the circuit completed with a large indifferent electrode applied over the bladder above the symphysis, is the proper way to proceed. A current with rapid interruptions from the fine secondary coil, gradually increased in strength up to the limit of passive toleration, and continued for five minutes every day, will accomplish good results. In less-aggravated cases, where it does not seem desirable to employ a urethral electrode, a vaginal electrode, with the uninsulated portion placed in a position so as to cause a current to pass through the bladder, may suffice. In young girls, where it is undesirable to employ either of the above methods, an attempt may be made to obtain the effect of the remedy by traversing

the pelvis by placing the electrodes one over the symphysis and the other over the sacrum.

Paralysis or paresis from a general or central (not local) cause is often benefited by electricity. Galvanism should be employed as a general nerve-tonic, and the coarse-wire faradization employed as a local muscular stimulant. The galvanic current may be given with one standard electrode over the lumbar region of the spine representing one pole of the battery, and the other pole applied over the symphysis pubis. From 5 to 8 milliampères will be easily tolerated, and it should be applied for five minutes each second day. On alternating days the coarse-wire faradization should be applied with the electrodes arranged one in the urethra or vagina (the active), the other over the symphysis (the indifferent), and a current of slow interruptions turned on, reaching a strength which will be easily tolerated, and then allowed to operate for from five to ten minutes. This treatment, together with other appropriate remedies, may be necessary for a number of weeks.

Bladder pains of locomotor ataxy may be greatly relieved by the systematic application once a day of the fine-wire faradic current through the parts affected. One pole, the negative, over the sacrum, and the positive over the symphysis, with the gradual increase of the strength with the fine interruptions until the limit of pleasant toleration is reached, should be the method employed. Time, from ten to twenty minutes.

Instability of the Bladder Due to Chorea.—In aggravated cases of chorea, where the bladder is momentarily relaxed and a state of slight but repeated incontinence exists, electricity has a remote but, nevertheless, gratifying effect. Here the static breeze, with its well-known qualities for relieving chorea, comes into play. The patient is placed on an insulated stool and a crown electric breeze is given every day, lasting for five minutes.

ECTOPIC GESTATION.

By CARTER S. COLE, M.D., and GEORGE W. JARMAN, M.D.;

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Definition.—It is hardly necessary to justify the terminology adopted. The term ectopic [Gr., ἔκτοπος; Lat., *ectopus*, *ectopicus;* Fr., *ectopique ;* Ger., *ektopisch*; anomalous in situation, out of place[1]] was originally proposed by Robert Barnes, adopted and popularized by Lawson Tait, and is to-day accepted as the only one which will satisfactorily embrace the various forms of the genus with which we have to deal. Extra-uterine would exclude the interstitial form (tubo-uterine) as well as the bicornate.

History.—In a study of the literature of the subject we are first amazed at its extent and next at its unreliability. Scattered throughout the journals of every tongue are found the records of individual cases. Parry[2] says: " Before the middle of the last century a number of cases of extra-uterine pregnancy had been observed and more or less accurately recorded; at least, so far as symptoms were concerned; though often without any correct knowledge of the condition which was being described. It was, however, finally established that a fœtus could be developed outside of the uterus, and in the year 1770 Antoine Petit[3] asserted that misplaced pregnancy was characterized by the following peculiarities." And he goes on to quote the same.

Greig Smith,[4] in giving the history of the operative treatment for this condition, refers to the cases of Christopher Bain, 1540; Noierus, 1591; Cyprian, 1694; but at the same time says: " The first genuine laparotomy for extra-uterine fœtation was probably that of Primrose, in 1594, who successfully operated on Noierus's patient when she again became pregnant." He credits John Baird, of New York, with the first operation in America, in 1764. But it was many years later that the frequency of this condition became understood by the profession, and that they may have been said to be on the outlook for such a state of affairs at a time when the knowledge would be of some service to the patient. Tait, of England, probably more than any one man, has contributed more to our practical knowledge of the subject by simplifying its pathology and giving an accurate account of his personal experience with forty

[1] Foster's Encyclopædic Medical Dictionary.

[2] Extra-uterine Pregnancy, by John S. Parry. Lea, 1876.

[3] Traité des Maladies des Femmes, Paris, vol. ii, p. 38.

[4] Abdominal Surgery, by J. Greig Smith. Philadelphia: Blakiston, 1887.

cases.[1] The works of Dr. William Campbell, of Edinburgh, 1842; John S. Parry, Lawson Tait, and J. Bland Sutton,[2] together with a number of monographs on various phases of the subject, notably that by John Strahan on the "Diagnosis and Treatment of Extra-uterine Pregnancy,"[3] will for a long time furnish a mint of information to any one desirous of mastering the subject.

Classification.—In view of the conflicting opinions as to the pathology of ectopic gestation, it is no easy matter to adopt a proper classification; indeed, as Parry has said, in regard to the determination of the class to which an extra-uterine pregnancy belongs, "It is one of the most perplexing questions which may come up for decision; and this is true not only during the life of the patient, but even after death has ended the stormy scene and an examination of the cadaver is being made, with all the care that skill and time can secure, with all the aid that the various instruments of modern science furnish." Up to 1824 the tubal, ovarian, and abdominal forms were recognized and described. The classical table of Dezeimeris[4] is nearly always quoted by writers on the subject, and is as follows:—

1. Ovarian pregnancy.
2. Subperitoneo-pelvic pregnancy.
3. Tubo-ovarian pregnancy.
4. Tubo-abdominal pregnancy.
5. Tubal pregnancy.
6. Interstitial tubo-uterine pregnancy.
7. Utero-interstitial pregnancy.
8. Utero-tubal pregnancy.
9. Utero-tubo-abdominal pregnancy.
10. Abdominal pregnancy.

A still simpler classification is by Parry,[5] and is practically the same as that given by Thomas[6]:—

Tubal Pregnancy.

Tubo-ovarian (the germ being arrested in the pavilion, which contracts adhesions with the ovary).

Tubo-abdominal (germ arrested in the same locality. The tube may contract adhesions with neighboring organs. If it does not, the chorion may project into the abdominal cavity, with a part of its surface bare).

Tubal proper (germ arrested between the pavilion and that portion of the oviduct which traverses the uterine wall).

Tubo-uterine (germ arrested in that portion of the tube which passes through the uterus).

Ovarian Pregnancy.

Ovarian proper (germ contained in the ovary, that organ remaining free from adhesions).

Ovario-tubal (germ contained in the ovary, which contracts adhesions with the pavilion of the tube).

Ventral or Abdominal Pregnancy.

Primary (ovum developed from the outset in the peritoneal cavity).

Secondary (development commences in the tube or ovary, the cyst ruptures, ovum escapes, and continues to live and develop in the peritoneal cavity).

[1] Diseases of Women and Abdominal Surgery.
[2] Surgical Diseases of the Ovaries and Fallopian Tubes, by Lawson Tait, vol. i. London, 1889.
[3] Blakiston, Philadelphia, 1889.
[4] Journal des Connaissances, Méd. Chir., January, 1837. Translated and quoted by Parry.
[5] *Loc cit.*
[6] American System of Gynæcology, vol. ii, p. 176.

But such a classification would hardly be accepted by the majority of writers on the subject to-day; indeed, if, as seems to be the case, Tait's views of the pathology of ectopic gestation be correct, his own classification would naturally recommend itself as being not only the simplest, but also more nearly in accord with the facts. It is as follows:—

I. Ovarian, possible, but not yet proved.
II. Tubal, in free part of tube, is—
 (*a*) Contained in tube up to fourteenth week, at or before which time primary rupture occurs, and then progress of gestation is directed into—
 (*b*) Abdominal or intra-peritoneal gestation; uniformly fatal (unless removed by abdominal section),—primarily, by hæmorrhage; secondarily, by suppuration of the sac and peritonitis.
 (*c*) Broad ligament, or extra-peritoneal gestation,
 (*d*) May develop in broad ligament to full term, and be removed at viable period as living child.
 (*e*) May die, and be absorbed as extra-peritoneal hæmatocele.
 (*f*) May die, and suppurating ovum may be discharged at or near umbilicus, or through bladder, vagina, or intestinal tract.
 (*g*) May remain quiescent as lithopædion.
 (*h*) May become abdominal or intra-peritoneal gestation by secondary rupture.
III. Tubo-uterine, or interstitial, is contained in part of tube embraced by uterine tissue, and, so far as is known, is uniformly fatal, by primary intra-peritoneal rupture (as *b*), before fifth month.

In this table Tait has given not only his classification, but also the terminations, and of the latter we shall speak a little later on. This is hardly the place to enter into a discussion as to the existence of the ovarian form of ectopic gestation, although it may be well to remark that a number of excellent authorities do not question its existence, while Tait[1] says: "Its possibility I admit, because I can easily imagine a Fallopian tube glued on to the ovary and deprived of its lining epithelium, permitting the contact of the spermatozoa with a follicle burst within the area (of the ovary) of adhesion. Then, the spermatozoa might infect the ovum before it escaped from the follicle; the ovum might adhere to the follicular wall and then develop. But there are so many contingencies in such a case and the doctrine of chances makes it so remote that its occurrence may be regarded as likely as the birth of a blue lion, or a swan with two necks, like a heraldic monstrosity,—a mere pathological curiosity." May not Sutton[2] have furnished, in his chapter on "Tubal Abortion," an explanation of many of the supposed cases of ovarian pregnancy? In the first place, he defines tubal abortion as "the term applicable to cases in which hæmorrhage takes place from a gravid tube, the blood entering the peritoneum through an unclosed ostium, the tube remaining whole"; and we may add here that this would rationally account for the so-called cases of primary abdominal gestation—if such a thing is possible—hitherto by many considered as unimpeachable

[1] *Loc. cit.*, p. 448. [2] *Loc. cit.*, pp. 327, 332.

simply because the tube was found unruptured. But, to return to the question of ovarian pregnancy, Bland Sutton sums up the matter by saying: "I am convinced that *ovarian gestation* has no existence, but that it may have been mistaken for *gestation in an ovarian sac*, which, of course, is a very different matter." However, Goodell[1] quotes and details the cases of Townsend,[2] Patenko[3] ("who discovered a specimen in the Pathological Anatomical Museum of St. Petersburg which seems to answer all the requirements of a demonstration"), Paltauf,[4] Zajaitsky,[5] Mann,[6] and H. T. Byford[7] in support of the existence of this form of ectopic gestation. Clinically, it is a matter of little import; and if the practitioner will realize that by far the greater number of cases are tubal at the outset, he will be better able to understand and treat an individual case. To sum up the matter in a few words, we have, from a clinical stand-point, these forms: Tubal, interstitial (tubo-uterine), and pregnancy in a bicornate uterus. At a later stage we have, if the patient survive the twelfth or fourteenth week, in the first variety a secondary abdominal pregnancy from rupture or a pelvic hæmatocele; in the second we may or may not have rupture; and in the third form the pregnancy will likely go to term. We will not consider the pregnancies in hernial sacs.

Terminations.—We have just stated that unless operative interference supervene the tubal form will almost certainly rupture by or before the twelfth or fourteenth week; it may rupture as early as the third week into the abdominal cavity, when the patient will most likely die from hæmorrhage, or, if she survive the rupture, adhesions may obtain and the case go to term; or it may rupture into the broad ligament, in which case the patient will most likely survive primary rupture and the gestation may go to term, or a secondary rupture into the peritoneal cavity may obtain; and, finally, a tubal abortion may take place and the ovum may continue to develop in the sac of the ovary or in the abdominal cavity, or, what is still more likely, be destroyed. In the interstitial form we are not prepared to accept Tait's statement, that it "is, so far as is known, uniformly fatal by primary intra-peritoneal rupture before the fifth month."[8] Goodell, in the article already quoted, relates the cases of Schwarz,[9] Martin,[10] Bolton,[11] Williams,[12] and Lowry,[13] in support of the

[1] Annual of the Universal Medical Sciences, 1890.

[2] Albany Medical Annals, January, 1889.

[3] Archiv für Gynakologie, vol. xiv and vol. xxx.

[4] *Ibid.*

[5] Centralblatt für Gynækologie, No. 51, 1888, and British Medical Journal, January 15, 1889.

[6] Archives de l'anthropologie criminelle et des sciences pénales.

[7] Journal of the American Medical Association, March 20, 1889.

[8] *Loc. cit.*, p. 443.

[9] Wiener medicinische Blätter, 1886.

[10] Zeitschrift für Geburtshülfe und Gynækologie, vol. ii, p. 416.

[11] Kansas City Medical Index, April, 1889.

[12] Medical News, July 27, 1889.

[13] Texas Courier-Record, September, 1889.

possibility of delivery being effected *per vias naturales.* We must not, however, lose sight of the fact that by far the greater number die from rupture, as Tait has stated. In the cases of bicornate uterus the case is apt to go to full term and be delivered, although rupture is in these cases a by no means uncommon accident. When the fœtus has gone on to full term in the abdominal cavity, or in the broad ligament, and the gestation sac remains intact after ineffectual labor, its contents may be, and usually are, diminished by the cessation of the secretion of liquor amnii and by its re-absorption; suppuration may ensue and be followed by discharge of the fœtal structures through the abdominal wall, intestinal canal, vagina, or bladder,—the second being the more usual form, according to Parry. The contents may be converted into a cartilaginous or bony substance, or into adipocere; or it may undergo calcareous degeneration; or it may undergo very little change. In any event it can hardly be considered an innocuous mass, which may be carried by the mother for an indefinite period."[1]

We have reserved until the last the question of tubal abortion occurring through the uterus, and the possibility of the conversion of tubal into uterine pregnancy. From a theoretical stand-point, if we admit abortion by the unclosed ostium,—and Sutton[2] says that such an event "can only occur during the first two months, for when the ostium is occluded the blood cannot escape without rupture of the sac,"—it is quite as rational to suppose that the same accidents may happen at the uterine termination of the tube. That a tubal can be converted into a uterine pregnancy by electricity or otherwise does not seem to be likely, although several cases have been reported in detail in which such seemed to be the case; and yet if an ovum can escape from the abdominal end of a tube and become engrafted somewhere in the abdominal cavity or in an ovarian sac, should it be more improbable that a similar event should obtain if the ovum escaped into the uterine cavity? It is not the likelihood but the possibility of such an occurrence on which we would lay stress.

Complications.—Probably the most usual complication is the occurrence of twin gestation. Parry[3] says: "Twin conceptions are much more frequent in extra-uterine than they are in normal gestations. In a large majority of these plural conceptions one ovum finds its way into the interior of the uterus, while the other is arrested at some point in its descent." A most interesting case of this kind, in which an extra-uterine fœtus impeded the delivery of an intra-uterine fœtus, occurred in the practice of Dr. Robert R. Stewart, of Philadelphia, and is quoted by Parvin.[4] In this case an incision was made in the posterior vaginal wall and the ectopic, blighted fœtus of six months was delivered; then the intra-uterine fœtus was delivered alive by the forceps. Pregnancy may occur while the woman is carrying an extra-uterine fœtus; but whether this be true

[1] Parry, *loc. cit.*, p. 162.
[2] *Loc. cit.*, p. 327.
[3] *Loc. cit.*, p. 138.
[4] American System of Obstetrics, vol. i, p. 717.

before the ninth month and after false labor is as yet unsettled. On the disposition of this question hangs considerable of the evidence in favor of superfœtation. After the child has been carried beyond term and become encysted, pregnancy is by no means impossible. Parry[1] says that, "of 22 women, 7 became pregnant once, 8 twice, 4 three times, 1 four times, and 2 five times, while carrying extra-uterine children." That women may more than once be the subjects of ectopic gestation was noted as long ago as 1594 by Primrose,[2] and many instances have been since recorded. The occurrence of intra-uterine tumors, as well as tumors of the unimpregnated appendage, is not an impossibility.

Duration.—We have already referred to this under the "terminations," but it may be interesting to quote here the table in Charpentier's work, edited by Grandin. It is unnecessary to observe that the classification differs from the one we have adopted:—

Of 26 cases of interstitial pregnancy, the duration in

1 case was	1 month.	3 cases was	4 months.
2 cases	3 months.	1 case	5 "
12 "	3 "	7 cases	not noted.

Of 88 cases of tubal pregnancy, the duration in

3 cases was . . .	4 to 5 weeks.	11 cases was . . .	4 months.
17 " . . .	4 to 6 "	4 "	5 "
9 " . . .	6 to 7 "	2 "	6 "
13 " . . .	6 to 8 "	2 "	7 "
4 " . . .	2 months.	6 "	9 "
17 " . . .	3 "		

In 185 cases of abdominal pregnancy the duration in

1 case was . . .	15 days.	2 cases was	20 years.
1 " . . .	3 weeks.	1 case	22 "
18 cases . . .	1 to 2 months.	1 "	25 "
4 " . . .	1½ to 2½ mos.	3 cases	26 "
5 " . . .	3 months.	3 "	28 "
22 " . . .	3 to 5 months.	6 "	30 "
15 " . . .	6 to 8 "	3 "	33 "
18 " . . .	9 months.	1 case	35 "
6 " . . .	10 to 12 mos.	1 "	39 "
24 " . . .	1 to 2 years.	2 cases	40 "
10 " . . .	2 to 3 "	4 "	46 "
23 " . . .	4 to 10 "	2 "	47 "
1 case . . .	11 years.	2 "	50 "
4 cases . . .	15 "	1 case	54 "
2 " . . .	16 "		

This will give some idea of the duration, although we are not prepared to admit that a tubal pregnancy, as such, ever goes without rupture beyond the fourteenth or, at the most, the sixteenth week.

Mortality.—This is an interesting matter, but not definitely settled. We know that the tubal and interstitial forms are almost uniformly fatal

[1] *Loc. cit.*, p. 141.
[2] De Mulierum Morbis et Symptomatis, lib. iv, p. 316; quoted by Parry.

from rupture. The general percentage has been variously given. Parry's[1] cases (499, in which the result is stated) gave a general mortality of 67.20 per cent.,—*i.e.*, 336 died and 163 recovered. The causes of death were:—

Rupture of the cyst,	174	Hæmatocele,	2
Pregnancy,	16	Septicæmia,	4
Exhaustion,	54	Intestinal obstruction,	8
Peritonitis,	24	Sloughing of cyst,	1
Hæmorrhage,	4	Traumatic inflammation of cyst,	1
into cyst after puncture to destroy child,	1	Starvation from rupture of stomach during gastrotomy,	1
into cyst,	3	Convulsions,	2
from separation of placenta,	3	Malacosteon,	1
from vaginal section,	1	Shock after gastrotomy,	1
from ligation of placenta in gastrotomy,	1	Not stated,	26
		Causes unconnected with gestation,	7

Thomas[2] gives thirty-three cases of his own in which there were twenty-two recoveries and eleven deaths. He quotes Kiwisch as giving 82.5 per cent. and Hening 88 per cent. in one hundred and fifty cases of the tubal variety; but Parry aptly observes, "Recovery is so rare after rupture that the physician has no right to allow the fact that it *may* occur to influence him in deciding upon a plan of treatment." Thomas, in speaking of his statistics, says he attributes his good results to (1) early and positive diagnosis, (2) prompt destruction of the life of the fœtus during the early months (of twelve thus treated all recovered), and (3) to an equally prompt resort to surgery in the later" (months of pregnancy). At all events, our belief to-day is that untreated ectopic pregnancy is exceedingly fatal.

Pathology.—The pathology of ectopic gestation resolves itself into a comparatively simple matter if we can regard the tubal as the usual form. In the first place, as Tait and Johnstone have shown, there is a loss of the ciliated epithelium of the tubes, thereby allowing the spermatozoön access to that part of the uterine appendage. Naturally, when the ovum becomes impregnated, there is, first of all, an increased vascularity, then an increased size of the tube, due, not as in the case of the uterus, to new muscle-cells, but mainly to the turgescence.[3] As the impregnated ovum develops the tube becomes distended and thinned, and sooner or later the tube ruptures, usually at the thinnest point. Sutton[4] says that during this time (four to eight weeks) a gradual occlusion of the abdominal ostium is in progress. "During the first four weeks the congestion of the parts causes turgescence of the fimbriæ, as well as of the muscular and serous tissues adjacent to them. When the parts are thus swollen the margin of the peritoneum adjacent to the ostium is very conspicuous and forms an irregular ring over the fimbriæ. In another fourteen days this ring projects beyond the fimbriæ, and, lastly, contracts

[1] *Loc. cit.*, p. 169.
[2] *Loc. cit.*, p. 185.
[3] Bland Sutton, *loc. cit.*, p. 112.
[4] *Loc. cit.*

and hermetically closes the ostium." We may add that the careful and repeated examinations, macroscopic and microscopic, of Sutton, give his views on the pathology a special force. In regard to the ovum the growth of the villi of the chorion is to be first noted, and we may add that on their detection microscopically depends the certain diagnosis of an impregnated ovum, and that their presence is indisputable proof of impregnation. We may also find other fœtal structures, though not infrequently an apparent blood-clot is found where tubal pregnancy is diagnosed, and the microscope alone shows the true state of affairs. Sutton says: "Chorionic villi, when seen in sections of an apoplectic ovum, are very easily recognized. Usually they appear as clusters of circular bodies; ten or more, in fortunate sections, may be counted together; more frequently they occur in groups of three or four, and often a wide section of clot may be examined without finding more than two or three. Under a low power they present an external layer of epithelial-like cells, the central space being occupied by irregular-shaped cells. When examined under high powers, the limiting layer is often formed of a perfectly regular row of cubical epithelium. Sometimes the interior of a villus resembles the stratum intermedium of an enamel organ. In larger villi a double row of epithelium may de detected." The only difference in the formation of the placenta is that it does not get the same support from the tubal mucous membrane as it does from the uterine. The concensus of opinion in regard to the decidua is that none is formed in the tube. Parry[1] says "1. In all varieties of extra-uterine pregnancy a decidua forms in the uterine cavity, as in normal gestation, but never surrounds the ovum. 2. The decidua is rarely retained until the completion of gestation, and thrown off during false labor. More frequently, if the patient go to term, it is discharged during the early periods of pregnancy in small fragments, and without producing pain; or else it is expelled *en masse* with symptoms of miscarriage. 3. The absence of uterine decidua when death has occurred from rupture of the cyst, even in the early stages of pregnancy, is not proof that the membrane has not been formed, but simply that it has been expelled before the death of the fœtus."

The situation of the placenta, whether above or below the fœtus, is an important matter, and, doubtless, a material factor in the treatment after rupture. If the placenta be above, it will after rupture be found adherent to peritoneum and viscera; if below, after the pregnancy has continued in the broad ligament, the fœtus may "disport itself among the intestines." In the former case—the placenta above—rupture occurs through the placenta, and it is not difficult to imagine the serious consequent hæmorrhage. In short, after rupture—short of the small hæmorrhages sometimes called ruptures referred to by Thomas[2]—the placenta elects its own attachment, and we must not be surprised to find that a mesentery, omentum, and viscera are in its grasp. The corpus luteum,

[1] *Loc. cit.*, pp. 72, 73. [2] *Loc. cit.*

as shown by Parry, forms as in normal pregnancy, except that, strangely enough, it is sometimes on the opposite side. The fœtus does not differ—except perhaps in size—from that of a normal gestation. The nourishment is supposed to be less and the development thereby not so full, although Pollac[1] details a case of combined intra- and extra- uterine pregnancy in which the reverse was true. The re-absorption, conversion into adipocere, mummification, etc., we have already noted in discussing the terminations; nor is it necessary to go into detail in regard to pregnancies in an undeveloped horn of a bicornate or interstitial uterus, as the pathology is that of normal pregnancy, except that in most instances there is much less increase of muscular tissue, and rupture of a grave character is almost certain to ensue. We must not forget that the uterus enlarges somewhat as in normal pregnancy; the cervix is softer than in the unimpregnated state, but not so soft as in normal pregnancy; the vagina is violet-hued; the breasts are plump and full, sometimes with milk at an early stage. The enlargement of the uterus does not compare, of course, with that in normal pregnancy, except during the first two or three months. Getting its attachment often at a number of points, the placenta is often of exceedingly large size. The placenta may be in the uterus and the fœtus in the tube or horn of a bicornate uterus, or *vice versâ*.

Etiology.—However paradoxical it may seem to say that we really know little or nothing about the etiology of ectopic gestation, and then discuss the matter at some length, such is the case. If we were to dismiss the subject by saying that any disease that has so impaired the ciliated epithelium of the tubes as to destroy their force in preventing the ingress of the spermatozoön and facilitating the egress of the ovum, the matter would indeed be a simple one. But we cannot do so; and every man who gives the history of a case is likely to give some different cause for its existence. Thomas[2] says: "I cannot look back upon my cases without being struck by the fact that a large proportion have occurred in strong, previously healthy working-women, who have given no reason for the fear that such a peculiar pathological condition would develop." In short, we need never be surprised to find the condition in any woman. However, when Parry, from the study of his cases, noted that long periods of sterility were very frequently present in the misplaced conceptions, he added a valuable point to our knowledge. That the periods of sterility are a cause of ectopic gestation we would not claim, but rather that such periods are the result of impaired functions of the appendages or uterus itself, and that the persistent effort that marks no other cause with which we are acquainted is covered by a final impregnation in that part of the tube at which the ovum is arrested and fertilized. Parry gives as causes the abuse of coitus, age,—and yet he himself says, "A young woman becoming pregnant for the first time immediately after marriage, or a matron already blessed with a numerous family, may be the victim of

[1] St. Louis Medical and Surgical Journal, May 10, 1871. [2] *Loc. cit.*, p. 180.

this distressing accident without our being able to discover any reason for it,"—emotional disturbances during coitus, pelvic inflammations, malformation of the genitals, mental influences, spasm of the tubes, tumors of the uterus, operations on the uterus, twin conceptions, uterine displacements, etc., etc.

"Women who have become pregnant, with a child outside of the uterine cavity, frequently show a previous inaptitude for conception. The interval between marriage and the first impregnation is frequently long. If the woman has borne children, a period of sterility frequently precedes the extra-uterine pregnancy."[1] He then enumerates a number of cases in which an interval of from five to eighteen years had passed between marriage and conception, and of from seven to twenty years in women who had previously borne children; so we should at least be on the lookout for such a pathological condition in women of this type. Thomas[2] gives the following table of causes:—

PREDISPOSING CAUSES.

(*a*) Prolonged nulliparity.
(*b*) Old attacks of pelvic peritonitis.
(*c*) Old attacks of salpingitis, especially if they have been specific.
(*d*) The existence of any uterine or tubal neoplasms.
(*e*) Old hæmatocele.

IMMEDIATE CAUSES.

(*a*) Strictures of tube, congenital or acquired.
(*b*) Obstruction from mucus or pus.
(*c*) Obstruction from swelling of mucous membrane.
(*d*) Pelvic tumor pressing on uterus or tubes.
(*e*) False membranes distorting or compressing tubes.
(*f*) Polypi in tubes.
(*g*) Cancer, sarcoma, or fibroma in tubes or in uterus, at the horns.
(*h*) Previous amputation of uterine body, the ovaries being left.
(*i*) Rupture of uterus or tubes from traumatism.
(*j*) Severance of fimbrial union of ovary and tube.

After all, except as in Koerherle's case, where the uterus was removed and the appendages left, we have no solid foundation on which to stand in detailing the etiology. In a large majority of cases we would probably never have had any opportunity to discover that the tubes were strictured or the subjects of new growths, or that a tumor was pressing on them, etc., etc. The strong probability is that these things, even when known, would simply increase the difficulty of making a differential diagnosis; and in looking over the whole field of etiological or concurrent factors, the periods of sterility seem to us to alone furnish a strong ground for being on the outlook for this condition in a woman supposed to be pregnant. As will be shown later, once suspected, the condition is by no means a difficult one to strongly prognosticate, and to sufficiently diagnose for all practical purposes. If we were to systematically examine every woman under our care as soon as she thought

[1] Parry, *loc. cit.*, p. 18. [2] *Loc. cit.*, p. 179.

herself pregnant, we should be saved, no doubt, great care and anxiety at a later day.

Symptomatology.—This naturally divides itself into a study of the symptoms before rupture, after rupture, and when the movements of the child can be plainly felt and the fœtal heart be heard, and until false labor at term; and, finally, after the termination of false labor or the death of the fœtus.[1]

Symptoms Before Rupture.—Probably the most important thing in this connection is to remember that there may be absolutely no symptoms; that the woman may not have the slightest intimation of any kind of pregnancy; and that rupture alone indicates to the skilled physician on the outlook for such an exigency the true state of affairs. If there are any symptoms they are those of a normal pregnancy,—*i.e.*, there is generally one or more menstrual periods missed; softening of the cervix, and change of color in it and the vagina, neither so well marked as in normal pregnancy; changes in the breasts, as in normal pregnancy; plumpness; change in areolar tissue about nipple; increase of Montgomery's tubercles; morning sickness, etc., etc. On the other hand, the menses may have appeared regularly, and none of the signs of pregnancy have been sufficiently prominent to call attention to it as a possible condition. Strahan[2] says of the catamenia, that "more commonly they continue irregularly and in *too great quantity.*" The "colicky" pains so often spoken of have given rise to considerable speculation and discussion. They did not escape Parry's attention, and, discarding peritonitis as their cause, he says "the true explanation is to be found in the wide differences between this and normal gestation. In the latter the ovum is developed in an organ the size of which increases in proportion to the growth of its contents. This growth of the uterus, it is to be remembered, is not a mere mechanical effect of the increase in the size of the product of conception, but is the result of vital nutritive changes by which its tissues are entirely and marvelously altered. On the other hand, when the ovum is arrested in the ovary or Fallopian tube it is developed in an organ which becomes distended mechanically by the growth of the fœtus, and which, not being intended by nature to perform such an important function in the plan of reproduction of our species, does not undergo those nutritive changes which will enable it to afford a nidus for the growing ovum. It appears probable that these paroxysms of colicky pain are produced by contractions of the fœtal cyst. The pressure of the fœtal cyst upon the contiguous structures may be another element in the production of this phenomenon," etc.

The repeated small ruptures seem to be the accepted explanation to-day. Add to these the belief of the patient, in many instances, of pregnancy, and we may go on to the vaginal examination. As before stated, if, in at least all women who have been sterile for a long time and

[1] Cf. Parry, p. 92. [2] *Loc. cit.*, p. 11.

believe themselves pregnant, we make a careful vaginal and abdominal bimanual examination, it will not be a difficult matter to at least make out a distension and enlargement of a tube; to feel a mass generally behind and close to the uterus; to bring out the fact that this tumor is often exceedingly sensitive to the touch, and that at times distinct ballottement can be evoked. At the same time, we will note the change in the uterus itself: slightly enlarged, cervix softened, etc., etc., all disproportionate to a normal pregnancy of the same period. Campbell[1] says that the uterus in ectopic gestation never becomes as large as the organ in a normal pregnancy of the fifth month. Add the history of the patient,—exposure, previous gestations, period of sterility, etc., etc.,—and, Lawson Tait to the contrary notwithstanding, the diagnosis can be, and has been, made with absolute precision.

The symptoms of rupture and after rupture are decidedly plainer than those before. In addition to the former, we have the sharp, agonizing pain, pallor and collapse of rupture, the fœtal heart and movements, with the advanced signs of pregnancy elsewhere. Unfortunately, we are too seldom able to ascertain anything but the history of rupture, and all our energies are bent on saving the patient's life; this is true in the cases in which the tube ruptures above the fœtus, and in rupture of a horn of the uterus or of the uterus itself. If the rupture is into the broad ligament the hæmorrhage is apt to be controlled, and we can diagnosticate a tumor of the broad ligament. The discharge from the uterus is apt to accompany the pains of this early period, and not so apt to occur later. The abdominal examination may or may not enable us, at a still later stage, to make out the character of the gestation. The tumor is supposed not to be so movable as the uterine form; the coverings are not so thick, and the fœtal heart and bruit are thought to be more easily heard, the fœtus more clearly and easily mapped out; and at this later period the development of the uterus is not in proportion to the development of the fœtus; the uterus, if it can be differentiated from the mass, is displaced, and, if a sound be introduced, its depth will be found to be much less than that of a uterus at the corresponding period of gestation. The pains may or may not have continued,—generally they do not, after the fœtus has broken the fetters of the tube into the abdominal cavity,—and it is in this form of gestation that these pains are present. However, with an accurate history and a careful examination we may be still unable to reach a conclusion; and if there be no indication to interfere, or if the case go to term, the woman is almost certain to have a spurious labor,—*i.e.*, the pains, with or without a bloody discharge, of a normal labor, but, of course, ineffectual,—and Parry quotes a number of cases in which this spurious labor was repeated at intervals of variable duration. It is during such times that the cases of interstitial pregnancy have been delivered *per vias naturales*. After spurious labor there is

[1] Thesis on Extra-uterine Gestation, Edinburgh, 1848, p. 107.

first death of the fœtus and then a rapid re-absorption of the contents of the cyst; exceptionally, it may be increased or remain the same. However, there is still a considerable tumor, which may undergo the various changes to which we have already referred in detailing the terminations of ectopic gestation. We have not pretended to try to give any difference in the symptoms of the various forms, though we might add that, if rupture occur in interstitial pregnancy or in the horn of a bicornate uterus, it is almost certainly fatal. We may give, in a nutshell, the symptoms, as follow:—

1. A history of previous sterility or of pelvic inflammation.
2. The presence of some of the signs of normal pregnancy.
3. Symptoms of abortion without trace of the fœtus.
4. The expulsion of fragments or of an entire decidual membrane.
5. Recurrent attacks of severe cramp-like or grinding pain in the hypogastric or iliac regions.
6. Great and sudden prostration following an attack of pain, with symptoms of internal hæmorrhage.

This probability would be made a certainty when, on physical examination, we found *per vaginam*:—

7. The uterus somewhat enlarged and displaced laterally, or forward and upward.
8. An elastic, fluctuant tumor on either side or behind the uterus, which was:—
9. Tender to the touch, and in which palpation excited severe pain.
10. By ballottement a floating body in the tumor.
11. The fœtal parts palpable through the abdominal walls.
12. Pulsating vessels in the vaginal walls near the tumor.

Per abdominem:—

13. A tense, very fluctuating tumor, possibly giving ballottement.
14. A tumor simulating the gravid uterus, but lacking the rhythmical contractility of that organ.
15. The sound of the fœtal heart.
16. The fœtal parts and movements.[1]

We have refrained from going over the numberless cases reported with this or that variation in their history; if the obstetrician and gynæcologist will ever keep before their minds the possibility of ectopic gestation in any case, it will not usually be a difficult question to determine the diagnosis as well as the treatment.

Diagnosis.—Prior to the past decade it was the rule rather than the exception for the presence of an ectopic gestation to be overlooked. To-day, however, the reverse holds true, as is amply testified by the scores of instances on record; and it may be stated that the condition is one which may usually be diagnosticated with absolute certainty by every man who bears in mind the peculiar, although uncertain, symptomatology, and who is possessed of average skill in the examination of the female pelvic organs. Unfortunately, the patients themselves only exceptionally come under observation before the usual period at which rupture occurs, is imminent, or has passed. Were the reverse true more lives might be saved without resort to surgery, and a greater proportion of instances of arrest of ectopic gestation would be recorded.

[1] Cazeaux and Tarnier's Obstetrics (appendix). Blakiston, Philadelphia, 1879.

The diagnosis of this condition must be considered during the pre-rupture stage and after this stage, when, as has been noted, the symptomatology alters greatly. The greatest difficulties by far surround the diagnosis when the case is most easily treated, namely, before rupture. That such cases have been diagnosed and the diagnosis substantiated on the operating-table is no longer a matter of doubt, even if we discard all those cases which have been reported by careful and competent observers as being arrested by electricity at this stage, and which were not proven by ocular demonstration.

Before rupture the history of the case yields the greatest amount of information. That extra-uterine pregnancy occurs most frequently in women who have either never before borne children or who have experienced quite an interim since the last pregnancy has been noted by nearly all observers. It seems also, from the recorded histories of these cases, that the great majority of them had been sufferers from previous pelvic disturbances. The patient usually seeks advice by reason of pain. The pain is described as being an unusual one, sharp and frequently cramping in character. This pain, however, is distinct from that described by patients which occurs at the time of rupture, for in the latter case it is more knife-like and far more intense. In a few cases the observers note that their advice was sought on account of irregular flowing, due to the discarding by the uterus of the decidual membrane.

Menstruation is nearly always disturbed, but the character of this disturbance is frequently misleading. Most often it is delayed to be followed by a flow which the patient will probably notice does not possess the ordinary menstrual characteristics, and which Jarman has, at least on two occasions, found very much brighter in color and failing to possess the characteristic menstrual odor. The flow will often be intermitting, and in a few cases the decidual lining of the entire uterine cavity will be passed intact. While the pain as referred to above is probably always present, and while the menstrual function may be irregular, no doubt these symptoms, in the larger proportion of cases, will be attributed by the patient to other causes, and she will not seek relief until rupture has taken place.

Morning nausea may or may not be present, but when it is found it becomes a valuable sign when taken in connection with others. One or both breasts will usually possess characteristics which accompany pregnancy. The elevation of the papillæ is frequently noticeable, even before any darkening of the areola or the presence of secretion.

Seldom will the patient's subjective symptoms be of value, for it is not often that she will believe that such a possibility as pregnancy, in any situation, is possible. In attempting to diagnose this condition before rupture the vaginal examination, when taken apart from the history and the ordinary signs of pregnancy, will be of but little value. The presence of a tumor on one side of the uterus is of such frequent

occurrence and due to so many causes that it is of but little diagnostic value *per se*. Should, however, the uterus be found to be enlarged and empty, its cervix soft, with a patulous os, it then becomes of far greater importance. In a few cases the gradual increase in size of the tumor has been reported, and stress has been laid on the pulsation which is present. It is hardly to be supposed that all these symptoms will be found in any given case, else the diagnosis would be more frequently made.

DIFFERENTIATION.—The conditions which are most likely to be mistaken for extra-uterine pregnancy before rupture are the following: Tubal enlargement from other causes, ovaritis, small fibroids, retroverted pregnant uterus, and abortion. The Fallopian tube may be distended with pus, blood, or water, and the pain due to this distension is very probably similar to that experienced from enlargement of the tube occasioned by the presence of an ovum. Tubal distension from these conditions may either cause menstrual disturbances or be coincident with them. The history of the case, together with the absence of any of the symptoms of early pregnancy, should make a differential diagnosis possible. An attack of acute ovaritis may very closely simulate this condition. The nausea is frequently present, and in not a few instances breast symptoms will be misleading. The vaginal examination, however, should reveal a rounded mass, and upon pressure causing the nauseating pain characteristic of the ovary only. Again, with these cases there is usually an elevation of temperature, which is rarely present in cases of ectopic gestation previous to rupture. The nausea accompanying acute ovaritis is not dependent upon any given time, but is often constant. The nausea of ectopic gestation is usually the same as that accompanying normal uterine pregnancy.

Small fibroids situated on the side of the uterus may be misleading, —the uterine hæmorrhage from this fibroid condition being a confusing element in making the diagnosis. The entire absence of any of the symptoms of pregnancy should make the differentiation possible.

A retroverted pregnant uterus will have many of the symptoms of extra-uterine pregnancy. The presence of pain, the undoubted symptoms of pregnancy, together with the fundus of the uterus felt in the *cul-de-sac* of Douglas, may very naturally simulate this condition.

The absence of the uterus from its normal position should cause suspicion of the real condition, and a careful examination should reveal it. Probably incomplete abortions are more frequently mistaken for this condition, and *vice versâ*, than any other. The placental tissue is mistaken for the false decidual membrane. The irregular hæmorrhage, the pain, more especially if there be any old pelvic trouble, and the undoubted signs of pregnancy may, for the time being, effectually obscure the true condition.

A careful examination under an anæsthetic should be of great value in clearing up the diagnosis and, where possible, should not be omitted.

The presence of a circumscribed mass on one side of the uterus should cause a consideration of the possibility of this condition; and if this mass continue to increase in size, together with symptoms of pregnancy, grave suspicions should be entertained that the condition is one of ectopic gestation,—and in a few cases the certainty of a *working* diagnosis may be established. There are well-established evidences that in many cases there are warning symptoms of the rupture before it has really taken place, and to this condition the term of incomplete rupture is more applicable than that of primary. By this term is meant that one or more layers of the sac which surrounds the ovum has been distended beyond its capacity of resistance, and that the tissues have yielded. In such cases hæmorrhage takes place into the sac,—and two symptoms for diagnostic purposes are added to those which have already been enumerated as belonging to this condition before rupture, namely, a very much more tearing pain and a rapid increase in size of the tumor. This increase is due to the hæmorrhage taking place into the sac. It is probable that this incomplete rupture takes place, in the majority of cases, before the far more alarming symptoms of complete rupture ensue. Complete rupture of the sac which contains the ovum will present two groups of symptoms, widely different in character, depending upon the direction of this accident. When the rupture is *into* the peritoneal cavity, the patient is at once in a condition both alarming to the physician and most hazardous to herself. It not infrequently happens that this accident will happen before the patient will give any serious consideration to her condition, and, in not a few cases that have been reported, it is stated that symptoms of rupture were the first to attract the patient's attention. It may be that the physician sees the patient for the first time after rupture has taken place, and, of course, will frequently have no previous knowledge of the pelvic condition. It has been stated by many that rupture of the gestation sac can scarcely be unappreciated, but the statement of Dr. Formad, of Philadelphia, that in his post-mortem examinations as coroner's physician he had found, within a very short period, eighteen deaths due to ruptured tubal pregnancy, would hardly prove these assertions correct.

Given a woman with, perhaps, a history of previous sterility, or that a number of years had elapsed since her last pregnancy, who has either skipped a menstrual period or who has experienced some unusual menstrual irregularity; who has had attacks of morning nausea; who has felt more or less pain in her breasts; who has had pelvic pain confined, it may be, to one side; who experiences an attack of acute, lancinating abdominal pain with severe collapse,—it may be fainting, anxious expression; cold, palid skin; rapid and feeble pulse, becoming gradually imperceptible; bedewed with a cold perspiration,—then we have very strong evidences of internal hæmorrhage due to the rupture of an extra-uterine pregnancy. Evidences so strong are these, in fact, that one would not hesitate to make the diagnosis as such.

As has been already stated, there are marked differences between the extra- and the intra- peritoneal rupture of the gestation sac. In the intra-peritoneal variety the general symptoms of loss of blood will increase in intensity, for the cause is still in progress. A spouting blood-vessel within the peritoneal cavity meets with none of nature's methods of checking hæmorrhage. Coagulation is very tardy, and the intra-abdominal pressure is not sufficient to check the loss of blood, which will rapidly destroy the patient's life. That the danger from comparatively small blood-vessels is not overestimated will be readily granted by all who have had occasion to open the abdomen for the purpose of controlling secondary hæmorrhage. Loss of blood even from small omental vessels has been known to cause the patient's death.

The vaginal examination in these cases of intra-peritoneal rupture of ectopic gestation will give but little information, unless, as happens in a very limited number of cases, the physician has cognizance of the condition of the pelvic organs which existed immediately before rupture. In this instance the mass which was felt may be considerably decreased in size if the rent has been extensive enough to permit the escape of the fœtus with its membranes. In many cases it will not be reduced in size to any great extent, but will have lost its tenseness. No sense of fluctuation will probably be noted, and no bulging of the *cul-de-sac* of Douglas will be apparent. All that will perhaps be discovered is a slightly enlarged uterus, a softened cervix, a patulous os, and a mass on one or the other side of the uterus or immediately behind it. If the mass is behind the uterus it will probably be more or less fixed, rounded in outline, and presenting a somewhat doughy and irregular feeling to the sense of touch.

The conditions which are most likely to be mistaken for intra-peritoneal rupture of extra-uterine pregnancy are: abortion; dysmenorrhœa; rupture of some viscus, with the escape of foreign matter into the peritoneal cavity; hæmatocele from other causes. The irregular hæmorrhage may be supposed to be from an incomplete abortion. If a chronically inflamed ovary and tube have been previously diagnosed, the true cause of the pain and the rapid pulse, together with the anxious expression, may be mistaken for pelvic peritonitis, an acute inflammatory condition having been added to the former chronic one. This mistake has been made in more than one case.

If the previous history of the case is gone over carefully and the symptoms are noticed to rapidly increase in severity, this mistake should be avoided. The temperature will also be a valuable diagnostic point. In pelvic peritonitis the temperature will be elevated from the beginning. In ruptured tubal pregnancy it will be subnormal or normal until peritonitis supervenes.

Hysterical patients, during an attack of dysmenorrhœa, may simulate this grave condition. Fainting, rapid pulse, and evident distress

may at first be misleading. The possibility of such a mistake need only be mentioned to avoid its occurrence.

The rupture of a viscus and the escape of either blood, pus, or fæcal matter will offer far more difficulty in differential diagnosis. The rupture of a pyosalpinx or ovarian abscess and the escape of pus into the peritoneal cavity will present several symptoms in common with the condition under consideration. The pain, with all the symptoms of shock, such as rapid pulse, cold perspiration, anxious facies, will be present and may be misleading. The same may be true of a ruptured appendix vermiformis which has become adherent to the pelvic organs,—a condition which not infrequently happens.

The previous history of the case would probably enable one to make the diagnosis. The symptoms of shock are of shorter duration, and well-marked evidences of peritonitis will rapidly replace them. Here also will the temperature be a valuable diagnostic guide. Where such septic material enters the peritoneal cavity the temperature rapidly becomes elevated, and in all probability will not at any time show any subnormal range. Luckily, however, the differential diagnosis in these cases is not of such vital importance, for the treatment will be practically the same.

It is claimed by some that blood escaping from the free end of the Fallopian tube in cases of salpingitis or in cases where, for some reason, the menstrual flow meets with obstruction and is forced back from the uterus through the tubes, enters the peritoneal cavity, and causes the condition of hæmatocele. Should this escape be great enough to produce effect upon the general circulation, it might be easily mistaken for ruptured ectopic gestation. Granting that this is a possibility and that the hæmorrhage continues until symptoms of shock are not only marked but found to be increasing, it would hardly be possible to make a differential diagnosis unless the abdomen were opened and the tube removed, and even then it is more than likely that different observers would take opposite grounds as to the presence of extra-uterine pregnancy. Loss of blood from this cause is, fortunately, not only rare, but not often extensive, and the flow takes place so gradually that nature is enabled to limit it by cutting it off from the general peritoneal cavity by means of a plastic exudate.

In the extra-peritoneal rupture of ectopic gestation the blood escapes between the folds of the broad ligament, and for this reason is limited. It can neither be so extensive because of its being forced into a closed cavity, nor does tardy coagulation occur. On the other hand, coagulation is hastened by reason of the stasis, and also on account of the pressure of connective-tissue fibres within the sac. Until the time of rupture the symptoms, of course, are the same as have been enumerated. The patient will have the same subjective and objective signs of pregnancy, and will experience the same tearing pain at time of rupture. In place of fainting, as so frequently happens in the intra-peritoneal

variety, she will experience simply a decided faint feeling, and will soon wear a blanched expression. The hæmorrhage is much slower, since the escaping blood must overcome the resistance of the distending broad ligament. For this reason the shock is rarely marked, the blood-vessels having time to adapt themselves to their lessened distension. There will be a subjective sense of increased fullness and weight in the pelvic region, and this may be accompanied by severe pain. Vesical and rectal tenesmus may be experienced soon after the rupture. It is, however, by the vaginal examination that the greatest amount of information may be gained.

The tense, elastic, broad ligament can be felt bulging into the vagina, and, in most instances, the uterus will be crowded toward the opposite side. The *cul-de-sac* of Douglas may also be bulging forward. The two layers of the meso-rectum may be separated, and upon introducing the finger into the rectum a constriction around its calibre will be detected. If the hæmorrhage has been extensive the mass may be palpated through the abdominal walls, and will be flat upon percussion.

The conditions which are most likely to be mistaken for extra-peritoneal rupture of ectopic gestation are: intra-peritoneal rupture of the same condition; hæmatoma of the broad ligament from other causes; inflammatory exudate in the cellular tissue of the broad ligament; pelvic abscess; cyst of the broad ligament.

There should be very little difficulty in making the differential diagnosis between an intra- and extra- peritoneal rupture. The very fact that in extra-peritoneal rupture the blood is limited by the folds of the broad ligament, and that this must cause bulging of the side wall of the vagina, can scarcely be overlooked during the vaginal examination. As stated above, none of the symptoms of loss of blood are so marked.

The subject of hæmatoma of the broad ligament received attention from various writers long before the great frequency of intra-ligamentous rupture of ectopic gestation was known; consequently, causes for its occurrence were multiplied, and, no doubt, were frequently theoretical. It is probable, in the light of recent investigations, that the great proportion of hæmatomæ of the broad ligament are caused by the rupture of extra-uterine pregnancies. It can be easily understood how the fœtus, so readily disintegrated, may escape detection even in those cases which go to the operating-table, and the collection of blood-clot be reported as due to some other cause, such as rupture of a vein.

For practical purposes all hæmatomæ in the broad ligament might be treated as if they resulted from the rupture of an ectopic gestation. The vaginal examination should enable one to distinguish induration due to old inflammatory exudate from a hæmorrhage into the folds of the broad ligament. From a pelvic abscess the condition would be distinguished by the sudden distension of the broad ligament in the one case, the gradual in the other; freedom from sepsis in one, its presence in the other. From a cyst

of the broad ligament the history alone would usually enable one to clearly diagnose the condition under consideration. In addition there should be an entire absence of any of the objective symptoms of pregnancy, and menstruation is rarely disturbed. In the large proportion of cases rupture into the broad ligament terminates the life of the fœtus, and it is disintegrated and absorbed, together with the blood effused. In cases of incomplete rupture usually, and almost always in cases of complete intra-peritoneal rupture, the life of the fœtus is destroyed. Rarely, however, development continues whether the rupture has taken place intra- or extra- peritoneally, the latter furnishing by far the greater number of cases which go on to full term.

Rarely will a diagnosis of the original site of these cases be determined. If the physician has had the case under observation at the time of rupture into the broad ligament and has been able to watch its after-development, of course the diagnosis of the original location would be easily determined. It is not often that one will be so fortunate as to have this previous knowlege of the case to aid him in making a diagnosis, and practically to be able to say that a given case is or is not a developing fœtus is not always easy. In these cases the subjective and objective symptoms of pregnancy become more and more characteristic, and often the patient will not be aware that pregnancy is not intra-uterine. The increase in size of the abdomen, which at first may be more marked on one side, usually after the fifth month becomes median. Pain is a symptom which seems to be constant, and unusual discomfort from the fœtal movements has been recorded. The cervix will be soft and the os patulous.

The crucial test in determining the diagnosis will be, of course, to find the uterus empty, and not corresponding in depth with the probable month of gestation. It will be necessary to take into consideration the following conditions in making a differential diagnosis: normal pregnancy; pregnancy in a bicornate uterus; ovarian tumors; fibroid tumors.

Probably more difficulty has been experienced in making the differential diagnosis between normal gestation and full-term extra-uterine pregnancy than any other. The diagnosis becomes peculiarly difficult in women with very thin abdominal walls, and who have previously suffered from ovarian or tubal disease. If the uterine tissue be thin, the fœtal parts will be so readily detected that the mistake may be made of supposing the fœtus to be extra-uterine. Adhesions from chronic salpingo-ovaritis will simulate the pain experienced in cases of ectopic gestation.

An examination under an anæsthetic may become necessary, and if the diagnosis still be in doubt the uterine cavity should be explored by the finger or sound. It would be wiser to terminate a normal pregnancy accidentally than to remain in ignorance of the real state of affairs. The finger coming in contact with the thin membranes inclosing the child, *in utero*, one should have no doubt as to the diagnosis.

Fortunately, bicornate uteri are rare, for they present grave difficulties in making a differential diagnosis. In these cases the sound alone might lead one entirely astray, if it entered the horn of the uterus which did not contain the fœtus. The introduction of the finger would, however, readily determine that the pregnancy was *in utero*, although it might not certify to the fact that it was in a bicornate uterus.

Ovarian tumors may be mistaken for this condition, but the absence of any of the signs of pregnancy, especially fœtal movements, heart-sounds, and ballottement, should make the differentiation possible.

Uterine fibroids giving no sense of fluctuation and being unaccompanied by the usual signs of pregnancy will present but little difficulty in making the diagnosis.

Treatment.—When we pass to the question of treatment it is at once apparent that the different stages of development and the different locations of the fœtus will materially influence the method of procedure. Means at one time advocated, of killing the fœtus by injecting various drugs into the sac or puncture of the sac, have proven so unsatisfactory that they will not be discussed. The treatment may be considered in the following stages: before rupture; at the time of incomplete rupture; after rupture into the peritoneal cavity; after rupture into the broad ligament. This last accident will have to be discussed in sections, namely: at the time of rupture; after rupture, the blood-clot having broken down and become septic; during fœtal development; at full term, the child being alive; before or after full term, the child being dead. There are only two methods of treatment applicable to ectopic gestation at all entitled to consideration: by electricity; by abdominal section.

Treatment by Electricity.—The use of this agent has certain limitations, which it is absolutely essential to bear in mind. At the outset it is to be remembered that a distinct contra-indication is evidence of rupture of the sac, whether intra- or extra- peritoneal. For practical purposes it may be stated, further, that the sphere of utility of electricity is limited to the period of gestation,—within three and a half months, in the first place, because the instances are very exceptional where spontaneous rupture does not occur within this period; and, in the second place, because, even though rupture should not take place, the ovum beyond three and a half months is too large to allow us to expect its disintegration and absorption with safety to the woman.

The earliest-recorded instance of the use of electricity in the treatment of ectopic gestation dates back to 1853, when Baccheti and Burci resorted to electro-puncture with success. Braxton Hicks, in 1866, next tested faradization in a case advanced to the third and a half month, but lost his patient because, in addition, he punctured the sac. Allen, of Philadelphia, in 1869, arrested an instance by faradism at the fourth month; and from this date on this method of treatment has become an accepted procedure, notwithstanding the violent opposition of late years

at the hands of gentlemen whose success from abdominal section for other conditions leads them to claim that the *ideal* method of treatment of ectopic gestation is by means of the knife. Notwithstanding this surgical tendency, it may be fairly claimed for electricity that, within the limitations stated, the agent can do no harm in the event of the diagnosis being erroneous, and may be depended upon as effective where the diagnosis is correct.

As regards the method of application, it is apparent from a study of the reported cases that electro-puncture should not be resorted to on account of the liability of fatal result. Galvanism and faradism have both proved successful. Where the former is used a milliampèremeter should be included in the circuit. Generally, for reasons which suggest themselves, faradism will be selected. One electrode is placed against the sac, per vaginam or rectum, and the other electrode on the abdomen. The current-strength should be within the tolerance of the patient. The applications should be repeated on alternate days until diminution in the size of the sac (which is proof of fœtal death) is apparent. Negative galvanism should then be used to promote absorption. These applications should always be made at the patient's house, and it is a wise precaution to keep the patient confined to her bed. Further, the physician should be constantly on the watch for rupture, so that in the event of this taking place into the peritoneal cavity the abdomen may be opened.

Every inch of ground of the advocates of electricity has been fought. Bitter and oftentimes unjust statements have been made. The advocates of this method of fœticide, however, have no apology to make, but simply offer the evidence of experience.

What are the objections usually urged against electricity? The first is, that the diagnosis is uncertain. These objectors would prefer to do an exploratory laparotomy, and thereby subject their patients to an operation which is fraught with danger, even under the best conditions and in the best hands, rather than attempt a procedure which carries with it no danger, simply because their method settles the diagnosis. The fallacy of this belief does not demand exposition.

Again, it is claimed that, the diagnosis being doubtful, there may be bad results from passing powerful currents through inflamed masses, for which extra-uterine pregnancy may be mistaken. That any bad result has ever followed the use of the *faradic* current, even in cases of pus-tubes, has not been shown, neither has it ever been demonstrated that the faradic current has ever caused suppuration in an inflammatory mass which did not contain pus.

Again, it is claimed that valuable time is lost, and the rupture thus made more certain, but this statement cannot be substantiated. The advocates of operative procedure in every case seem to forget that, with the death of the fœtus, danger of rupture has passed, and that this should be accomplished in every case if the current is strong enough. They all

advise *waiting* until one can be reasonably sure of the diagnosis, but during this waiting and watching period they refuse to use a means which has proven successful in the hands of many competent observers.

Again, many have argued that the death of the fœtus did not preclude the further danger of placental growth and consequent rupture. This can only be theoretical. In Brothers's well-known and carefully-collated series of cases no such accident occurred; indeed, the occurrence is one which would seem to rest purely on the unsupported statement of Tait, whose bias in favor of abdominal section is so generally recognized as to deprive his opinion on this point of all weight. This is a question, however, which has quite recently been thoroughly canvassed by D. Berry Hart, of Edinburgh, and his conclusion, deduced from a careful study of all the recorded cases, is that there is absolutely no warrant for the assumption that the placenta continues to grow after fœtal death; on the contrary, he reached the definite conclusion that the increased bulk of placenta at times met with is produced purely during the life of the fœtus. The fact, indeed, that the placenta has been found to be larger than would correspond with the size of the dead fœtus, judging by the comparative sizes of the two as found *in utero*, can prove nothing until we are able to say that an extra-uterine live fœtus is always associated with a placenta no larger than that found in normal gestation. It is also claimed that, even if the death of the fœtus is assured, suppuration and not disintegration with absorption will follow. This can be easily answered. In not a single case, as reported by Brothers, where electricity was used before the fourth month did this result occur, and in the exceptional single case (Chadwick's) the fœtus had advanced to the fifth month, or after the period when it is claimed that disintegration will take place.

Again, why is it that we do not see more pelvic abscesses following cases of rupture into the broad ligament with death of the fœtus if this accident is so likely to follow? The most rabid advocates of the knife agree that these cases of extra-peritoneal rupture should be let alone, and that they will usually be taken care of by nature.

To sum up the matter, it is clearly evident that experience up to the present time has proven that this method of fœticide is not only successful, but that the results obtained by this method of treating ectopic gestation before rupture can compare more than favorably with any other method in vogue.

Treatment by Abdominal Section.—When there are evidences of incomplete rupture, the symptoms of which have already been enumerated, electricity should no longer be used. This is simply a warning of the far more instant danger which awaits the patient. When such a diagnosis has been determined the rational method would be to perform a laparotomy and remove the gestation sac.

After rupture into the peritoneal cavity, when symptoms of hæmorrhage are unmistakable and the patient's life is jeopardized, abdominal section should be performed at once. This is no more than is called for in any case of hæmorrhage; the bleeding-point must be sought and tied. Rarely will one be able to operate at the time of, or immediately following, rupture. It is usually after grave symptoms have made their appearance, and often after they have progressed beyond control, that the surgeon is called.

The abdomen should be opened, and, even before the free blood and blood-clots are removed, it is the surgeon's duty to check any further hæmorrhage. A clamp can be guided down to the broad ligament by the fingers, and that portion of it between the tumor and the uterus compressed. After this the operator can take time to clear the field of blood and clots. The method of removing the sac is identical with that in performing oöphorectomy. If the pregnancy has been interstitial the uterine tissue will require careful suturing,—often the sac will have formed strong adhesions and a surface denuded of its peritoneum will result from the enucleation. Hæmorrhage from this surface is frequently difficult to control except by actual pressure, and strips of iodoform gauze will be found invaluable for this purpose. Drainage should be resorted to, preferably by means of iodoform or borated gauze.

Expectant Treatment in Extra-peritoneal Rupture.—After rupture into the broad ligament, experience has shown that the expectant treatment is the course to be adopted. Operative interference is rarely called for. If the patient is kept in the recumbent position until the blood-clot is clearly becoming smaller, but little other treatment will be necessary. Rarely the blood-clot will become septic and pus formation results. An opening should then be made into the sac from the vagina. The pus must be evacuated, the sac thoroughly washed out, and drainage resorted to. In a small proportion of cases the embryo survives this rupture and continues to grow.

The patient from now until full term is in constant danger from the possibility of a secondary rupture into the peritoneal cavity. Every day the increasing size of the child and placenta adds to the danger of this accident. The life of the mother only is to be taken into consideration. The chances that development will continue and the child reach full term are small, and even if it should, and be safely removed, it rarely survives the first few weeks. Many have also stated that it is often deformed. Inasmuch as the continuous growth of the child constantly increases the dangers which the mother must encounter, it is the duty of the physician to destroy it as soon as it has been determined that development is taking place. If development has continued beyond the fourth month, the death of the child will not insure the mother's safety. The sac may have formed adhesions with loops of intestines, and through this source sepsis may have entered the system. In such cases it is necessary to

carefully watch the patient, and as soon as any symptoms of sepsis are apparent laparotomy should be performed. The sac is to be opened, the decomposed fœtus removed, and the opening into the sac stitched to the abdominal wall. Usually the placenta will have become freed from its attachments and may be removed at the same time; should it be adherent, however, it is better to allow it to come away in fragments. Free drainage should be kept up.

If the child has reached full term and is alive, a very interesting complication may force itself upon the surgeon for decision. The little notoriety which one gains from performing a brilliant operation should not influence the conscientious surgeon for a moment. Neither must sentimental ideas have the least weight in forming his decision. He must decide this question, "Should I operate and probably save the life of a child which at best will stand but few chances of surviving, and by so doing greatly add to the dangers of the already unfortunate mother; or should I delay the operation and thereby permit the child to die and the placenta to lose very much of its vascularity, if, indeed, not all of it, and by this delay very much enhance the chance of the recovery of the mother?" To those who will look at this question purely from the stand-point of the woman, and who will consider, as they ought, the ectopic fœtus as simply a parasite, and who will, moreover, remember the course they would wish pursued in their own family, the choice will unquestionably be in favor of delay. No one will deny the legitimacy or the imperative duty of the physician of resorting to fœticide in the non-controllable vomiting of pregnancy or in uræmic complications. It is astonishing that so eminent a man as Tait should make the assertion that men who hold the view that the killing of the child in developing extra-uterine pregnancy is justifiable are "on the level with abortion-mongers!" This statement is too illogical and unworthy its source to merit discussion.

After the child is dead and the placental circulation has ceased, the operation is fraught with far less danger. It is contended by some that no operation should be performed until symptoms supervene, but nature's tedious methods of relief and the many known dangers to which the patient must be exposed do not seem to justify non-interference. The abdomen should be opened as soon as the placental circulation has ceased (and this fact can be ascertained by the absence of the placental bruit), the fœtus removed, and the sac-wall stitched to the abdominal wound. As stated above, the placenta is occasionally detached and will be found lying free in the sac. This will very much simplify the convalescence. The sac should be drained and allowed to close from the bottom. If the placenta is still adherent no attempt should be made to free it, for it will come away gradually through the opening. Convalescence is hastened if a vaginal opening can be made at the same time, thus providing perfect drainage. The sac should be frequently irrigated with antiseptic solutions.

TREATMENT OF CANCER OF THE UTERUS BY ELECTRICITY.

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Various Forms of Cancer of the Uterus.

These may be divided anatomically or histologically for the purpose of treatment. The anatomical classification answers the best. We may, therefore, divide the uterus into three zones: (1) the vaginal portion of the cervix; (2) the cervix proper and the endometrium; (3) the body of the uterus. The form of malignant disease which is most commonly found on the vaginal surface of the cervix is true epithelioma. I use the word in the old acceptation of the term, to mean a form of carcinoma consisting principally of squamous epithelial cells, characterized by the presence of nest-cells, and also of projecting processes which dip down into the subcutaneous or submucous tissue, and as perfectly distinct from what modern pathologists now call adeno-carcinoma.

The best example of the latter is found in scirrhus of the breast, while the most typical example of the former is found commencing on the outer surface of the body. The epithelioma of the portio vaginalis either begins in the stratified epithelium on the vaginal surface or in the transitional epithelium at the os externum. Most of the so-called cases of cancer of the cervix are instances of cancer involving this part, but not originating in it. The cases, however, in which cancer had originated in the portio vaginalis and in which the disease was observed at an early period are very few (Ruge and Veit).

In the majority of cases the epithelioma extends only toward the vagina and does not penetrate deeply, and this fact must be borne in mind in giving a prognosis. The course taken by the disease seems to be influenced by the deep fascia, which offers a higher resistance to its encroachment than the loose, submucous, cellular tissue, and it is only after the disease has extended laterally for some inches that it seems to be capable of extending into the pelvic cellular tissue. During the early stage its greatest thickness may be stated to be about three-fourths of an inch. Very often the cervical canal is not involved. The earliest subject of this form of cancer which I have seen was 30 years, and the latest over 60. The most common period for it to appear is between 30 and 45, and it is more frequent during menstrual life than after the menopause, and is more common in married women than in single women. The symptoms are not marked during the early stages. Slight hæmorrhage is usually one of the first, and is very often passed over and put

down to some other cause. There is generally also a white or yellow discharge, and until a late stage an absence of fœtor. The duration of life with this form of disease appears to be longer than either when the disease begins in the cervix or when it begins in the body, and the probability of infection of the system is less.

Cancer of the Cervix.

In considering cancer of the cervix a few words may be said on the question of diagnosis. In several instances cases have been sent to me diagnosed to be early carcinoma of the cervix, but which, on examination, turned out to be simple erosion, and it is only those who are in constant practice and seeing these cases that can give a reliable opinion, and even they may be mistaken.

One point of distinction between an erosion and malignant disease is the softness of the former and the comparative hardness of the latter to the touch, even in the early stage, and for this reason an erosion merely consists of an hypertrophied condition of the mucous membrane of the lower cervical canal, and the extension of the columnar epithelium and glands from the endometrium on to the vaginal surface of the cervix. When examined through a Ferguson speculum an erosion has more the appearance of a granulating ulcer. If touched roughly it may show a few points of hæmorrhage, though very little in comparison with that which follows even gentle manipulation when the disease is cancer.

The form of malignant disease which is usually found commencing in the cervix is that now designated "adenocarcinoma," and the change appears to commence in the glands. They increase in number and assume forms which are not seen in health. The chief characteristic changes are those observed in the epithelial lining. The cells, instead of being arranged in a single layer as in health, often become stratified in multiple layers and fill the gland so as to obliterate its lumen. Each cell contains many nuclei instead of one, and are of various shapes and occasionally columnar in form. In other cases they are small, round, or oval, and the columnar cells appear to go through an actual transition to round cells. The disease more often begins in the lower part of the cervix and sometimes from more than one centre,—the posterior lip more often than the anterior. The forms assumed are various. Many form a polypus or papillary growth on the surface simulating a cauliflower in appearance, or else a small nodule. The direction of the growth when the disease assumes a cauliflower form is downward into the vagina, and in this case does not invade the cervix proper for more than three-fourths of an inch, but it very soon infects the cellular tissue around.

In other cases, when the disease commences as a small nodule, the growth extends upward and downward, continues to invade the wall of the cervix until it has passed through its whole thickness and has reached the cellular tissue around. As a rule it does not at first pass beyond the

internal os, or not until the cellular tissue around has been invaded. Ultimately it involves the whole of the cervical wall. Usually the mucous membrane of the vagina is not involved. At a later stage, when the lymphatic glands are infected, those along the internal iliac vessels are the first to become diseased. It is most common between 40 and 50, about the time of the menopause, and may occur as early as 28 or as late as 80. The chief symptoms are hæmorrhage, pain, discharge, and wasting.

Hæmorrhage appears to come on earlier in this form of disease than when it starts as a true epithelioma of the portio vaginalis. The tissue of the malignant growth is more friable. It is very important to bear in mind that the irregular hæmorrhages which so often occur as a normal condition during the monopause may be simulated by the hæmorrhage caused by malignant disease of the cervix, and whenever there is any doubt about the diagnosis a careful examination should be made. Pain is very often absent in the early stages, and is commonly only present in women of a neurotic type. Discharge comes on soon after hæmorrhage has appeared, both these symptoms being due to breaking down of the malignant tissue. The discharge at first is only slightly offensive. It is usually watery in character and either greenish or yellow. Wasting does not occur until the rapid growth of the malignant tissue and the continual loss by discharge have interfered with nutrition. Occasionally, but not often, micturition is more frequent than natural.

Cancer of the Body of the Uterus.

This is not so common as disease of the cervix, and is more difficult to diagnose. The histological character of these cases is the same as that for the cervix. The disease starts from the epithelium of the glands, it tends to involve the whole surface of the body, does not often extend into the cervix until the late stage has arrived, and in some cases it may even protrude through the vaginal orifice. It may pass through the muscular wall of the uterus and produce local peritonitis and adhesions to neighboring organs, and, finally, invade the parts which thus become adherent. It differs from cancer of the cervix and of the portio vaginalis in that it nearly always commences after the menopause. It is most frequent between 50 and 70. Hæmorrhage is the first symptom that comes on, and patients not infrequently fail to consult their physician at first because they are under the impression that menstruation has returned. Pain is felt more often and earlier than in cancer of the cervix, and is sometimes of great severity. It is supposed to be produced by contraction of the uterus excited by the growth. An offensive discharge usually comes on rather later. On bimanual examination the uterus is found to be enlarged, and this is very often marked before extension takes place to the cellular tissue around. It must be borne in mind that, although there may be no physical signs that the

cellular tissue around the uterus is invaded, the disease may have extended through the upper surface of the uterus into the peritoneum and on to the intestines.

PATHOLOGY OF CARCINOMA.

The pathology of carcinoma still requires elucidation. Although we have no actual proof of having arrived at a correct estimate of its origin, we have a very considerable knowledge of its histology, clinical characters, rate and mode of progression. By sifting, comparing, and weighing this evidence, I shall attempt to deduce an hypothesis upon which treatment can be based.

One of the most striking facts shown by the microscope is that the cells of all new growths have been derived from the healthy tissues, and that in the carcinomata the chief offenders are the epithelial. We distinguish the malignant from the normal, first, by noticing that, under the microscope, the grouping of the new cells in cancer formations is different from that of the normal tissues; secondly, that clinically new tissue is formed without apparent cause for its presence.

The formation of new tissue and new cells is not, however, confined to tumors and carcinoma, but takes place as a normal process in inflammation whenever a lesion of the body has to be repaired. In the light of modern pathology, we may say that this never occurs without a specific cause, such as an injury of some kind or the presence of a microbe or parasite. Knowing, as we do now, that the inflammatory new growth of tubercular disease and of syphilis is due to the presence of microbes, we are at once led to ask: Is it not likely that the presence of some hitherto undiscovered microbe is the cause of malignant tumors? What is the evidence in support of and against this hypothesis?

In the first place, all those diseases which have been found to be due to microbes give rise to inflammation. It is true that this may vary very considerably in its manifestations according to the variety and intensity of the disease and the part of the body attacked, but it has definite limits which are not transgressed. We never at any time find the grouping of epithelial cells which is characteristic of cancer. Inflammation differs in other respects from malignant disease. It progresses either to suppuration and cicatrization, or to fatty degeneration and absorption. The onset is associated with fever and tenderness and pain. The malignant new growth, on the other hand, arises insidiously and rarely causes pain or fever at the commencement. Its progress is persistent, has no limit, and more often goes on to ulceration instead of cicatrization. If, then, carcinoma is due to the presence of a microbe, we are driven to the conclusion that this microbe differs from every other specimen of its class by exciting unique forms of new growth instead of the well-known phenomena of acute or chronic inflammation.

Investigators have also failed in their endeavors to find a microbe

characteristic of carcinoma. No one could have bestowed more care and patience on this branch of science than Messrs. Shattock and Ballance. But all their efforts—carried on for years—have only given negative results. As the evidence stands at present, we must acknowledge that the balance appears to be against the microbe as the cause of carcinoma.

There can, I think, be little doubt that every cell in the body is inhibited by the nervous system from active proliferation; the reins, so to speak, are only relaxed when an injury renders the formation of new tissue a necessity. One of the striking points about malignant disease is the indefinite proliferation of cells. Contrast this with the proliferation of healthy cells that takes place in a healing ulcer. The rate of growth of the new granulation tissue is quite as rapid as malignant disease. We can observe the formation of new blood-vessels, the transition of the epithelial cells into spindle-cells and, finally, fibrous tissue, and the proliferation of epithelium. All those changes go on in the carcinoma, but the grouping of these elements is entirely different from that of granulation tissue. Further, the latter does not continue to proliferate indefinitely; as soon as the lesion is repaired the process abruptly stops. Now, physiologists have taught us that most, if not all, of the cells of the body are controlled by the nervous system.

The nerve filaments have been actually traced to the individual cells. If we now compare the growth of carcinoma with inflammation, we come across some very remarkable facts. Bearing this in mind, and also the remarkable way in which granulation tissue rapidly grows to the extent required and then ceases, we are forced to the conclusion that the process is under the control of the nervous system. We thus see that, although granulation tissue and carcinoma can both form new blood-vessels, fibrous tissue, and fresh epithelial cells, they differ in two important points,—the grouping of these structures and duration of their growth. With the former it has a definite limit and then ceases; the latter is uncontrolled, progressive, and ceases only with the death of the patient or destruction by treatment. Apparently, then, the growth of granulation tissue is under the control of the nervous system, while that of cancer is independent of it. No trace of nerve-filaments has ever been found in malignant tumors. Cohnheim states that "the glandular carcinomata never secrete partly because they are not placed in typical connection with the excretory ducts, but principally owing to the absence of the required innervation." To put the proposition into other words, we may suggest that the malignant growths consist of cells that are uncontrolled by the nervous system.

The conditions associated with the commencement of malignant growths contribute evidence in support of this view. One of these is the depressed condition of the nervous system, as in the case of the sore tongue of an inveterate smoker. In many it is constitutional, while in others it has been brought on, by trouble or other causes, before or about

the time of the onset of the disease. The result of this is that the controlling power over the healthy cells is in a weakened condition. Another point of common observation is the liability of malignant disease to commence in some lesion of chronic inflammation liable to repeated irritation; for instance, sores on the tongue, erosions of the cervix, eczema of the nipple, and numerous others. When a healthy ulcer is irritated by an application of nitrate of silver the formation of granulation tissue is hastened, and the ulcer will quickly heal up if it is then protected from further injury. But if the irritation is continually repeated, which we so often find has occurred with sufferers from cancer, the damage is equal to the repair and healing cannot take place, but at the same time the proliferation of cells is overstimulated. Is it not possible that this active proliferation, occurring in a subject with depressed or weak nervous force, may cause some of these cells to escape from control, commence an independent existence, and form the so-called malignant growths?

The apparent want of resistance by the healthy tissue to the inroads of the disease can be explained also by this supposition. We have before stated that the healthy cells are in an apparent state of inhibition, and only proliferate under a distinct stimulus, of which there are a great variety. But the malignant cells being derived from the healthy tissues remain passive, while the malignant exercise without control the chief function of all living cells, viz., to reproduce their kind and then die. Some pathologists have thought that the disease was not so much due to a power in the malignant cells of forcing their way and displacing the healthy tissues, but was entirely due to a want of resistance in the normal tissues themselves; but this view does not appear to me to be tenable, because directly we entirely destroy a portion of a malignant growth surrounded by healthy tissues it acts like a foreign body and resistance to its presence is shown, either absorption or expulsion taking place. We may say that the disease is not so much due to a deficiency of defensive power as to an increased offensive power consequent on the unrestrained proliferation of the cancer-cells.

The hypothesis then which, to my mind, seems to harmonize with the several factors of the life and progress of malignant disease is the following: "That cancer consists of new cells which have been formed during the process of repair or inflammation, and in an active state of proliferation have escaped from the control of the nervous system."

The natural deduction to draw from this hypothesis is that, "although the cells of malignant growths multiply more rapidly than those of healthy tissue, the absence of a nerve-supply places their vitality, and more especially their recuperative power, on a lower plane than the latter."

In what way can we take advantage of this difference in recuperative power? I believe it is quite possible that it may be some day achieved by medicinal means, and no doubt this would be the most effectual way of getting at all the cells. The disadvantage would be, that every healthy

cell would be injured in order to kill a few malignant, unless some substance can be found that has a selective action, which is highly improbable. The time-honored method of excision by the knife undoubtedly prolongs and possibly in some instances it cures, if the whole of the disease can be removed. I have notes of cases where excision has led to immunity for some years, while in other cases I am convinced it has progressed more quickly than when left alone. The explanation of this is not far to seek. If the whole of the disease is removed there is no recurrence unless it actually recommences.

When some cells are left behind these continue to grow and very soon give evidence of their presence, and the increased blood-supply necessary for the healing and cicatrization of the incision gives them extra nourishment and enables them to grow more quickly than before. Another cause of increased growth after excision can be explained by the recent publication of experiments on auto-inoculation; although there was a great outcry at the time, there can be no doubt that the knowledge of this factor is of the greatest possible value to every operator. It appears to me to explain those cases of recurrence which I sometimes see, where the tissues on each side of the cicatrix are simply studded with fresh foci of disease within a few months after excision. If instead of going well round the tumor the knife cuts into it, and is then used for an incision into the healthy structures, the latter might become inoculated and fresh foci be started. It is only upon this supposition that one can explain the vast differences observed as the result of excision. Possibly washing out of the wound with a strong antiseptic might act as a preventive. The hypothesis which I have brought forward serves to explain this fact. The worry and haste, and I may almost say the want of philosophy and the greed for riches in modern civilized life, entail a constant drain on the nervous system, and lead to that condition of depression so often associated with malignant disease.

Another and a very important factor bearing on recurrence is, I believe, the general constitution of the patient. This appears to me to vary within very wide limits, from the typically healthy subject, who seems to commence the disease through a combination of unfortunate circumstances, to the feeble, toneless subject, who seems to start it under the slightest provocation. The former may be free for some years, if the disease is quite stamped out, but the latter, under any circumstances, will probably soon start it again, even if it be completely destroyed in an early stage. The mortality from cancer, in spite of excision and other methods of treatment, continues to increase. It may almost be said to be the chief medical problem of the day. May not the good results claimed by those who use strong caustics be due to their power of destroying the infectivity of the cells of the growth? There are many diseases for which we can never hope to do much, because they are due to decadence of life or to structural changes that only a divine power could recreate; but cancer,

in a large majority, occurs in people who are in other respects strong and sound or only suffering from some trivial complaint. The general tendency of the specialists appears to run almost entirely on the use of the knife, to the neglect of other means. There are some cases where excision is invaluable, but there are others where it is out of the question, and it is our duty to humanity to see what other means can be adopted.

TREATMENT OF CARCINOMA.

The battery which I find most convenient is Stöhrer's hospital (Dresden), of 40 cells; two or three of these are linked up together. The rail upon which the commutator slides is continued from one battery to the other, and the circuit is continued by means of a copper wire between the two last elements of each battery. By this means two or three batteries, as required, are converted into one. No rheostat is used. This form of battery is chosen on account of its simplicity, its high electro-motive force, and the ease with which it can be overhauled and repaired when necessary,

The elements are zinc and carbon dipping into dilute sulphuric acid into which is placed a small quantity of bisulphate of mercury. When the zincs are well amalgamated and the battery freshly charged, it has an electro-motive force of 1.8 volts per cell. It has to be borne in mind, in selecting a battery, that no one form will answer for all purposes. If the battery is easily portable the cells must necessarily be small, and the high internal resistance which follows from this diminishes the amount of electrical energy that can be obtained. In other portable batteries, even when size is not considered, but where the cells are covered in so as to avoid splashing of contents during the journey, I have found that either the electro-motive force was not high enough or that they were so complicated one could not always be depended upon to work properly.

The Stöhrer battery cannot be carried about in a charged condition, but all that one requires is to take 1 quart of strong sulphuric acid and 2 ounces of bisulphate of mercury. Water can always be obtained. The acid is diluted to 1 part in 12, and the cells can be filled with an ordinary milk-jug, and with due care the batteries can be taken long distances by rail or steamer without any breakage occurring. On one occasion the jolting of the train fractured one of the carbon plates; so it is advisable to take some spare ones. The galvanometer used is Edelmann's. It may be said that this is not the most accurate nor yet the best kind for the measurement of currents, but it must be remembered that when using an alternating current the conditions are different from those when using the constant. The needle of the Edelmann galvanometer is a pivoted one, and is kept in balance by two bars of steel. It therefore moves when influenced by electricity much more slowly than any suspended needle. In most galvanometers, when a powerful current of 300 or 400 milliampères is turned on, the tendency of the needle is to swing so far that it gives no

measurement whatever. The needle of the Edelmann galvanometer, when a powerful current is suddenly turned on, swings very little farther at the instant of turning on the current than it would if the constant current were being used.

Various forms of needles are used for applying electricity to malignant growths. Those that I find most useful consist of a stem of steel attached at one end to a copper wire for connection with the wire of the battery, and at the other end fixed to a platinum point. The steel is insulated with a thin layer of vulcanite rubbed down until it is perfectly smooth and flush with the platinum point. These needles are made of different lengths and different thicknesses. Some have sharp points, some rather blunt, some quite blunt. The latter are useful when it is necessary to pass near a large blood-vessel. A special form of electrode is used for passing the current from the upper part of the uterine wall. It is like the needle already described, but the steel is the length of the uterine sound; at the lower part is a vulcanite handle with a lock and screw for making connection. Over the whole of the stem is a movable cellular sheath, which is made sufficiently long to slide over and cover the point. It thus enables the operator to pass the electrode up to the fundus if necessary without any risk of the sharp point catching in the mucous membrane of the endometrium on the way, and when the point of the electrode is in position the indicator of the needle enables him to expose as much of the trocar as may be required.

Electricity has a variety of action according to the method of application used. 1. A mild constant current seems to have a nutritive action. 2. The chemical action at each pole is the caustic. 3. By using a very powerful current, breaking and alternating it, a disruptive and traumatic action is produced throughout the space between the poles. The great difficulty of the constant current is that most of its action is confined to a small space around each pole, and that the caustic action at the positive pole is not the same as the caustic action at the negative pole. In my experiments published in the "Transactions of the British Gynæcological Society" for 1888, I was unable to find any decomposition of molecules between the poles, although under certain conditions an alteration in their composition may take place. Now, with an alternating current there is, of course, some chemical and caustic action at each pole, but the amount of destruction is the same and equal, each pole being alternately positive and negative, but the amount that takes place is comparatively small. The traumatic action produced by the sudden impact of a powerful alternating current of 400 milliampères through the tissues between the two points of insertion is chiefly relied upon.

The method of application will depend on the character of the growth. It is an interesting and curious fact that malignant disease may have high resistance in one part, shading off into low resistance in another. The chief difference found in carcinoma of the uterus is

between the true epithelioma and the adenocarcinoma. The squamous cells of the epithelioma containing cell-nests and deriving epithelium from the hard epithelial cells have a much higher electric resistance than carcinomata derived from glandular cells; and so much is this the case that they even offer a higher resistance than the healthy tissues which usually surround them. The consequence of this is, that it is exceedingly difficult to force a current through it; and even if one pole or both be placed in the morbid growth itself, electricity appears to very often pass around by the healthy tissues. With the adenocarcinoma this does not appear to be the case, though in some varieties, such as that which occurs in the breasts, the centre of the tumor, if of long standing, very often has a high resistance; but I have not observed this in the uterus.

To my mind electricity should never be used in the treatment of disease unless it is better than other methods, and there are occasions when the knife should be preferred to the application of electricity; for instance, when a malignant growth has such a high electrical resistance, on account of its age or other cause, it is better to excise it with a knife, watching the case carefully, and at the onset of recurrence apply electricity while the cells are young and good conductors. For the latter condition it has a very great advantage over the knife. There may be several small points of new growth, and in order to get at these with the knife it would be necessary to do a severe and sweeping operation; but a needle could easily be passed into each focus and only the diseased tissues destroyed, without causing shock, without hæmorrhage, and very much to the patient's advantage.

Epithelioma of the Portio Vaginalis.—These cases, taken at an early stage, are very promising, because the disease, as a rule, has neither extended deeply nor invaded the lymphatic glands. If an operation is decided on, the patient should be kept in bed for a few days, and an antiseptic douche should be used until the vagina is aseptic. The patient is then placed on the operating-table, in the lithotomy position; ether is administered. The next step to be taken will depend on the size and extent and characters of the growth. If, for instance, there is a large ulcer with a good deal of soft, breaking-down tissue, it is better, as a preliminary measure, to scrape this with a blunt curette, and apply strong perchloride of iron to check the bleeding. In applying the curette no force should be used; only the friable material which comes away easily should be removed. One advantage of doing this is that the parts can be made thoroughly antiseptic,—a consideration not to be lost sight of when we may require to puncture the cellular tissue around the uterus through the vaginal wall.

In other cases, where the ulceration is slight and the tissues superficial, the curette is not required. Now, in the treatment of epithelioma by electricity it is necessary to rely upon the caustic action of the two poles for the reason stated before, that this form of growth has a higher

electrical resistance than the healthy tissues. Sims's speculum is passed into the vagina; the cervix is taken hold of by a strong pair of tenaculum forceps and pulled down as far as possible to the vaginal outlet by an assistant. A second assistant stands by the batteries, watches the galvanometer, increases the number of cells in the circuit, and alternates the current by means of a commutator, according to the direction of the operator. Two needles at a time only are used. One of these should be run into the growth; the other, held in the operator's hand and having a sharp point, makes a trench into the healthy tissue all around the growth. The depth of this will depend on the case. Through this edge the needle should be pushed under the growth; a current of 400 milliampères is left on for ten seconds, and then alternated by the assistant with the commutator for another ten seconds. The position of the needle should then be changed. In this manner the whole of the growth must be undermined, and when the operation is finished the whole of it should look bloodless and almost black. When the growth is extensive it may be necessary to do two operations. As a rule, I never go on for more than an hour at a time. For carcinoma of the cervix the same precautions must be observed to keep the patient aseptic. As the ulceration is generally more extensive in these cases, the use of the curette, for scraping away all the dead tissue available, becomes more necessary. It must be done thoroughly, and if there is a cauliflower excrescence this must be removed. Hæmorrhage can usually be checked by applying a pledget of cotton-wool soaked in the strong solution of perchloride of iron. Bleeding vessels must be secured in the usual way.

When the patient is in a fit condition and the vagina is clean and free from odor, a second operation may be done with electricity. The patient is placed in the lithotomy position and the batteries and assistants arranged as before. It is advisable for the anæsthetist to keep his finger on the pulse and indicate to the operator any serious variation. A blunt electrode is now passed up to the fundus and a needle is passed through the vaginal wall into the cellular tissue surrounding the uterus. The current is then flashed through and alternated. It should be allowed to pass for three seconds at a time. After ten interruptions the position of the electrodes can be changed. The blunt electrode should, during half the operation, be brought into contact with the ulcerated surface which has already been curetted. A second blunt electrode may be passed into the bladder and the current sent through from uterus to bladder, and also to the rectum. The number of punctures required and the duration of the operation will depend entirely upon the extent of the disease, and must be left to the judgment of the operator. It is advisable to repeat the operation at the end of ten days or a fortnight. The patient can then be left alone and seen occasionally.

FACIAL BLEMISHES.

By HENRIETTA P. JOHNSON, M.D.,

WITH ILLUSTRATIONS FURNISHED BY

GEO. H. FOX, M.D.,

NEW YORK.

Hypertrichosis [1] has been defined as an unnatural growth of hair. This development may be abnormal as to location, quantity, or quality. For convenience of description it has been divided into two general classes,—(1) hypertrichosis universalis and (2) hypertrichosis partialis. Of the former class, which is always congenital and not amenable to treatment, it is quite safe to say that there cannot be found on record a case where the entire human body has been covered with hair. Certain parts are always free from hairy growth, because the skin at these points is not provided with hair-follicles, from which alone the hair-root can spring. If we accept the Darwinian theory, the epidermis was here, as elsewhere, originally differentiated into hair-producing elements; but the friction of ages, atrophy from disuse, and various other causes have, in the course of time, resulted in the obliteration of the reproductive hair-cells, as on the palmar surfaces of the hands, the plantar surfaces of the feet, the third phalanges of the fingers and toes, etc. If this be so, why may not atavism, or reversion to type, at least claim attention in our attempts to get at the etiological factors in cases which, for want of a better term, we have been satisfied to style as "freaks of nature"? Fecundation by a hairy parent and so-called maternal impressions received at the moment of conception or during fœtal development have been considered as possible causes. Heredity has furnished some interesting records, notably in the Schwe Maong family, in which the hairy predisposition was traced back for several generations; Adrian Jeftichjew, whom Virchow has described, handed down his hairy coat to his son Fedor; but from this observed order of facts, which is very limited, no general rule can be established. Unna's theory that hypertrichosis is probably due to arrested development, the lanugo persisting and growing, the change between the primitive and permanent type failing to take place, has strong advocates. Overdevelopment of hair has been associated with deficiencies in the ossific formation of the lower jaw and a lack of development in dentition; and since the teeth are, as early as the second month of fœtal life, formed by solid cylindrical prolongations of the stratified epithelium of the surface into the depths of the embryonic mucous membrane, and the hair-follicles appear, about the end of the third

[1] Hirsuties, polytrichia, trichauxis.

month, as solid cylindrical outgrowths from the stratum Malpighii, it is not altogether an unreasonable hypothesis that overdevelopment in one may be compensatory to a lack of development in the other. Lombroso's microcephalic girl furnished an example of hypertrichosis, and she also presented unmistakable evidences of imperfectly-developed teeth, and the inferior maxillæ were asymmetrical. One celebrated case exhibited three abnormalities,—(1) hypertrichosis universalis; (2) neuropathic papillomata on the right side of trunk, on the right arm, and on the left side of face; (3) on the left half of the mouth several teeth were small and irregular.

Of the notable cases of hypertrichosis that of Esau stands earliest on record. Referring to his birth we find, in sacred history, that the first of the twins "came out red, all over like a hairy garment." In Genesis, ch. xxvii, v. 11, 16, we read: "And Jacob said to Rebekah, his mother, 'Behold, Esau my brother is a hairy man and I am a smooth man.'" "And she put the skins of the kids of the goats upon his (Jacob's) hands, and upon the smooth of his neck," in order to complete the deception to be practiced on the father. The hairy condition then, as now, must have been exceptional, and medical literature reports but comparatively few cases. In addition to those already alluded to, the family of Ambras and others might be mentioned, detailed descriptions of which may be found in any book on dermatology.

Hypertrichosis partialis—the form which is acquired, or, rather, the form which makes its appearance after birth—is distinctly localized, occurring in larger or smaller areas on the face, especially on the cheeks; over the upper lip, on the chin and submaxillary regions, not infrequently between the eyebrows, more rarely on the end of the nose, and occasionally we find long and coarse hairs growing on the helix of the ear. This abnormal growth of hair also occurs on the chest between the breasts, and markedly on the forearms and legs. Facial hirsuties, if it mar the comeliness or comfort of the patient, is that form which is of interest to the medical practitioner. Matthew Arnold says, "Our sense for beauty and our sense for propriety are such that any eccentric departure from a prevailing condition, or even by an oddity in appearance, as when we wear a hat of a very old fashion, disturbs our mental equilibrium." That many women suffer acute mental distress because of a beard-like growth of hair upon the face, which is both unsightly and unnatural, admits of no question; and, more, that one case has come under my own observation where the repeated application of caustics has resulted in deforming cicatrices, which only served to make the hirsuties more noticeable. I know of one beautiful and attractive woman who would not marry, lest the hairy tendency which had made her own life a wretched one, and which she had tried by every known artifice to conceal, might be transmitted to her female offspring. These are only a few of the very many extremely annoying cases; but the number of women who

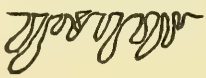
do not in one way or another attempt to remove the conspicuous hairs from some part of the face by the use of tweezers, scissors, razors, or epilatory nostrums is decidedly in the minority.

The etiology of hypertrichosis acquisita is involved in obscurity. Numerous and laborious have been the investigations as to its causal factors, and varied are the theories deduced, but all have proved more or less unsatisfactory. Virchow suggested a neuropathic basis, as he observed that the lines of hairy development tended to follow the course of the fifth encephalic nerve. Facial hirsuties has often been marked in insane women. Even the hair of the head is said to undergo peculiar changes, and it is claimed that a diagnosis of cerebral troubles can be made from an examination of a lock of the patient's hair. Dr. George Henry Fox, to whom we are indebted for the most careful and persevering investigation of this subject, says that he knows very little about it. Some of his patients are sthenic, others weak; some exhibit extreme nervous irritability, others are phlegmatic; some incline to obesity, others tend to emaciation. Women of both blonde and brunette type are represented,—the married, some of whom bear children, while others are childless, and the unmarried of all ages, ranging from the period of puberty, when all the cells of the female organism are in a state of progressive activity, to the climacteric age, when the system is employed in adjusting itself to changes which tend to establish a lower grade of vital force. Dr. Fox admits that heredity is noted in some cases; and he has expressed the opinion that excessive growth of hair, either in man or woman, is an aberration of nutrition, and not a sign of increased vitality, for, he says, "The Sampsons of the present day are clean-limbed."

That hypertrichosis is sometimes connected with deficient menstruation admits of no question. Sterility and other uterine troubles have been accepted as factors, especially in those cases where the hairy growth has seemed to be coincident with or a sequel to the symptoms and physical signs of such disorders. Be the cause what it may, there is only one known method by which superfluous hair can be removed permanently, and at the same time leave the skin in a condition which tends to become, after a short time, almost normal, and that is by electrolysis. This treatment, in order to insure a successful result, requires time and patience for the operator and a considerable degree of fortitude and endurance on the part of the subject operated upon. The most skilled practitioner must not expect, from the most skillful operation, speedy and quite perfect results; a certain proportion of the hairs will return or be replaced by weaker ones, and a downy sort of growth may persist after all the longer, stronger hairs have been removed. We can very readily understand why this is if we examine the hair-structures histologically:—

The hair-follicles are formed by involutions of the epidermis (as

shown in the accompanying cut), and are not always in the same direction of obliquity; and their shape, which is like a funnel, may be somewhat modified by pressure of the surrounding tissues, and their bases are not equidistant from the surface. The hair-follicles present, on the free surface of the skin, a mouth or opening; the other extremity runs through the corium into the middle strata of the subcutaneous tissue, there terminating in a sort of bulb, which ensheaths a small papilla or nipple-shaped projection. This papilla is composed largely of fibrous tissue, and is well provided with cells. A loop of capillary blood-vessels supplies its nutrition. Just over this structure is placed a special row of germinating cells, always in a state of active multiplication, and from these new cells are continually being formed. The older cells become elongated to form the fibre, and others undergo special modification to produce the medulla and the cuticle of the hair. To devitalize this portion of the hair-structure and render it incapable of cell-production is the aim of the electrolytic operation, and it can be accomplished in every ordinary case. The difficulties in the way of even an extraordinary development are not by any means insurmountable; but an expert management of the electric



current, which can be acquired only by practice, is absolutely essential, the trained hand soon learning to perceive how, when, and where to introduce the electrolytic needle in order to get the best results.

Outfit Required.—A large chair, a galvanic battery, a rheostat, a galvanometer, two insulated wires or conductors, one sponge-electrode, one needle-holder, a case of jewellers' broaches, one pair epilating forceps. Any zinc, carbon, or chloride-of-silver battery of about 20 cells answers the purpose, and the battery-fluid can be prepared as follows: Sulphuric acid, 1 part; bichromate of potash, 1 part; water, 20 parts. This is about one-half the strength of the ordinary fluid, and is much better, because (1) a greater number of cells may be used and the zinc and the fluid will not be decomposed so rapidly; (2) the battery will not polarize so quickly; (3) the battery will not get heated so soon as when the full strength is used. A small quantity of the bisulphate of mercury (as much as can be taken up on the point of a penknife) placed in each cell re-amalgamates the zinc elements, thus preserving them from rapid decomposition, and at the same time the strength of the current is not diminished. The selection of a needle is of great importance. It must be exceedingly fine (the coarser needles invariably produce scars) and of very flexible steel. The needle-holder is of various patterns. Dr. Leviseur's was so constructed that the needle could be inserted at a right angle. Some holders are provided with springs by which the current may be made or broken, but the simplest form and the one to which we become accustomed by

constant use is the best. Magnifying lenses are not considered helpful, although they have been highly recommended.

The patient being placed in position, near a northern window if possible, to secure the best light, is directed to hold the insulated handle of the sponge-electrode (wetted with warm water) in her right hand. The needle is then placed at the side of a hair and allowed to glide into the follicle. If the needle meet with any resistance, it should be withdrawn and re-introduced. If properly done, the patient is not subjected to the slightest pain. The holder is then dextrously transferred to the left hand, the needle remaining in the follicle, and the hair is seized with the epilating forceps, which are held all the time in the right hand. The circuit is completed by the patient herself, by pressing the sponge-electrode with the palm of the left hand. The hair should merely be held; the slightest traction should be avoided. When loosened by the electrolytic action, it seems almost to jump out of the follicle. It is well to have a small piece of black velvet in a convenient spot, on which the hairs can be laid. They sometimes stick to the forceps, and are troublesome; moreover, you can see the number removed; and it is well that the operator (for the work is trying to the strongest eyes) should limit himself to fifty at the outside, twenty-five or thirty at one sitting being the number generally removed. It is not advisable to treat hairs that are too close together, for if vesicles result they may coalesce and form cicatricial tissue. It is not necessary that the current should be strong enough to excite any inflammation at the point of introduction of the needle, although a frothy appearance and a sort of wheal have been accepted as evidence of a successful action of the current. After a few sittings the skin, which may be hypersensitive at first, seems to acquire a sort of tolerance for the operation, and the most nervously-organized patient becomes accustomed to the unpleasant sensation, and seems to suffer but slight inconvenience. The moral effect of successful treatment is beyond any question, and is so gratifying in every instance that it would justify even a more lengthy and painful mode of procedure.

The Latin word " nævus " means a spot or blemish. In most of the text-books the term is generally applied to a localized abnormality of the skin; hence it includes affections which differ widely pathologically and clinically. An effort at classification should be made by which they can be dissociated in name, as they are in reality. Angioma simplex, or nævus vasculosus, familiarly known as wine-mark, fire-mark, strawberry-mark, port-wine stain, etc., is the result of an increase in the number of or the dilatation of the newly-formed or of the pre-existing capillary blood-vessels, an affection which is always congenital, although its external manifestation may escape notice until some time after birth. Under the microscope we find an increase of cells in the blood-vessel wall (thickening), or it may be considerably thinned and slightly dilated, or pouched and sacculated, and the connective-tissue stroma in which

the capillaries lie imbedded is more or less proliferative. The vessels themselves are twisted and tangled, tied in hard knots, and heaped up irregularly, and sometimes the mass is raised above the surface; but they are formed in the skin or in the tissues lying immediately underneath it, and are seldom projected above the plane of their origin. Such nævi are especially prone to occur on or about the face. They may be limited in size to a pin-head or so large as to cover one-half the forehead, the entire cheek, and, running down and around the neck, extend to the suboccipital region. As a rule these growths occur singly, but the condition which favors the development of one may give rise to a number, and upon close examination we may find spots here and there upon the rest of the body-surface, generally on the same side as the facial deformity, rarely crossing the mesian line, for the distribution is not bilateral, and, even if it occur on both sides, there seems to be no tendency to follow a symmetrical arrangement. The shape is apt to be irregular, sometimes sharply defined; or it may be lost in the color-shading, which ranges from dark red or purple to a faint, pinkish tint. The color always disappears under pressure (a diagnostic point), and it is heightened by vasomotor disturbances, exercise, or anything which tends to increase temporarily the blood-circulation, while a diminished flow of arterial blood will cause a vascular nævus to appear dark and blue. The form most often seen in children and women with delicate skins is the capillary nævus, and its life-history is variable. In some cases it tends to disappear spontaneously (involution). In others it steadily increases in size for a year or more, and then, for some unknown reason, further development seems to be arrested; or it may remain as at first, undergoing in the course of years scarcely perceptible changes.

The aim of every form of treatment for the removal of nævus vascularis is to set up such an inflammation as will result in the occlusion of the lumina of the capillary vessels, and thus cut off the blood-supply to the part. The galvanic current accomplishes this more quickly and more satisfactorily than scarification, puncture, or any other method. A single needle, if we could have the required time and patience, would undoubtedly enable us to score more brilliant successes for the electrolytic treatment, but such a procedure is practically impossible in a case of extensive nævus. An instrument containing eighteen or twenty needles, which are firmly set in a brass disk, one or two millimetres apart, facilitates the operation greatly, and is the one generally employed. The needles must be exceedingly fine, with very sharp points. If pressed quickly into the skin the pain is not by any means unbearable, and on completing the galvanic circuit the electrolytic action breaks up the capillary net-work to which the nævus owes its existence. Ten or fifteen cells of an ordinary zinc-carbon battery are quite enough to use, and the needles should not remain in the tissues more than fifteen to thirty-five seconds. When the skin around the needles begins to blanch and rise

Nævus Araneus treated by Electrolysis.

BEFORE AND AFTER TREATMENT.

up in wheals, galvanic action is well established. On withdrawal of the current this effect soon passes away, and only the points of puncture remain visible. In about twenty-four to thirty-six hours small crusts will be formed where the needles have pierced, and when these crusts fall off—for they must not be removed by artificial means—small, slight, punctate cicatrices will show themselves. We must wait a fortnight or even a month before judging of the effect of the electrolysis. A repetition of the operation will then be indicated, and treatment must be kept up until the color is approximately normal. The texture of the cuticle is necessarily somewhat altered, for nature is quick to detect and resent any injury to the delicate structures which she rears and guards, and makes it an invariable rule to replace a destroyed tissue with one of an inferior quality. It is, however, gratifying to note that as time elapses the skin gradually approaches its normal appearance. The superabundant cell-growth is more or less absorbed, and other changes take place which tend to obliterate the lines of scar-tissue. No patient will submit to this operation, or to any other of the sort, unless old enough to realize the deformity and feel willing to endure much for the sake of its permanent removal.

Nævus araneus, a form of telangiectasis known to the laity as spider-cancer, consists of an enlargement or dilatation of an arteriole in the centre, from which the distended capillaries radiate outward. It is probably due to a slight traumatism. Treatment consists in the introduction of the electrolytic needle in the central aneurismal loop and allowing it to remain for a few seconds, or until evidences of galvanic action are unmistakable. A repetition of the operation is seldom necessary. Another form of telangiectasis is the arborization of vessels on the cheeks and noses of coachmen and others exposed to cold, harsh winds, etc.

In nævus pigmentosus, or pigmentary mole, we find an increase in the deposition of pigment-granules in the columnar cells of the rete mucosum. In lentigo and cloasma we also find a condition of hyperpigmentation. The pigmentary mole is described by most writers as a congenital, circumscribed hyperpigmentation of the skin. Dr. Fox says it is rarely congenital. This affection may appear as a larger or smaller discolored spot (macule) or a more or less prominent excrescence, and its original character and shape usually persist during the life of the individual, rarely undergoing any marked changes excepting those depending upon or incidental to the age and growth of the patient. In old age, under irritating influences, such nævi seem to incline to malignant degeneration. A pigmented nævus may occur on any part of the body, but unless on an exposed portion, as face, neck, or arms, or so extensive as to be considered of interest as a monstrosity (as the bathing-tights form, for example), is rarely presented for examination. The size of a pigmentary mole may range from a scarcely discoverable dot to an area of discoloration so large as to cover an anatomical region. Its

color ranges from a very delicate fawn to a deep-brown shade or even black, but we must be careful not to mistake black seborrhœic dirt-spots for actual pigmentation. Numerous subdivisions of this class are found in text-books based on some individual peculiarity, as when accompanied by a growth of hair (nævus pilosus); in this form the peculiar discoloration of the skin constitutes the essential difference between a hairy mole and hypertrichosis. In a hairy nævus the skin is apt to be considerably thickened and is covered with a growth of short, bristle-like hairs resembling the hide of an animal not only in quality, but in the direction in which the hair lies. Hyde, Sir Morrant Baker, Lavater, and others have reported cases of hairy nævus of greater or less interest, but the most remarkable case of cure by electrolysis is that recently treated by Dr. Fox and reported in the *Journal of Cutaneous and Genito-Urinary Diseases.*

Pigmented nævi have been noted to follow nerve-tracts (n. spili zoniformes). Then we have the warty nævus, hypertrophy of connective tissue (n. verrucosus), the fatty (n. lipomatoides), and the fibrous (n. fibrosa), *et al.* These moles are sometimes soft and supple, the skin retaining almost its normal character, occasionally hard (proliferation of non-differentiated elements) and very often of mixed varieties, differing widely in shape, size, and color. They are rarely single. If one be found there are usually two or three and perhaps a larger number scattered here and there over the surface of the body, singly or in groups, in different stages of development.

Indications for treatment are to remove the hairs as described in the operation for removal of superfluous hair, and to treat the mole in the same manner as for the removal of wine-mark, etc.

ELECTRICITY IN DISEASES OF THE SKIN.

By PLYM. S. HAYES, M.D.,

CHICAGO.

General Therapeutics.

The application of electricity to the treatment of diseases of the skin naturally divides itself into the surgical and medical uses.

Surgical Therapeutics.

The surgical application is, in itself, subdivided into the galvano-cautery and the electrolytic, or galvano-caustic.

GALVANO-CAUTERY.

The application of this means is limited to the actual destruction of tissue and superficial searing to produce stimulation. The galvano-cautery is but one form of the actual cautery, and wherever the actual cautery can be of use the galvano-cautery is of equal service. It has some advantages, however, among which may be mentioned the facility with which the cauterization may be limited to a small surface and the ease with which the temperature can be maintained at any given degree for an indefinite time. The old claim that a small amount of electricity leaves the cautery electrode and, by passing through the surrounding tissue, alters the cell-life to an appreciable extent is not proven, and does not merit further mention.

The freedom from pain following a galvano-cautery operation can best be explained on the ground that the electrode was so hot that the destruction of tissue was limited to the parts in immediate contact with the electrode—the volume of the electrode being so small that there was but little effect on the tissues from radiant heat. Should the destruction of the tissue be greater than above described and the skin and fascia pierced, there is thus formed a vent for the serum that may be poured out, and freedom from pressure and consequent pain which would have occurred had this exit not been provided.

ELECTROLYSIS, OR GALVANO-CAUSTIC.

In electrolysis we have a means of treatment that has a much more general scope in skin diseases than the galvano-cautery. We can destroy tissue as effectually by means of electrolysis as by the cautery. The limitation of the destruction of tissue by electrolysis consists in the pain produced by the current and the time consumed in the operation. The pain depends upon the strength of the current and the susceptibility of the patient, which is different for each case, and cannot be foretold.

In electrolysis we possess the means of destroying tissue either by an acid or alkaline caustic, as we use either the positive or negative pole. We can make our needle which constitutes the electrode first positive and then negative, then positive again, thus getting the alternate effect of an acid and alkaline caustic at will.

The appearance of the eschar at positive and negative pole are such as would be produced respectively by an acid or alkaline caustic. At the positive or acid pole we find that the destruction of tissue is less extensive than at the negative or alkaline pole. The acids liberated at the positive pole coagulate the albumen of the tissue, thus forming a barrier, which prevents the action of the liberated acids on the tissue beyond. On the other hand, at the negative pole the alkalies are liberated, and, as they do not coagulate the albumen of the tissues, the area of destruction is much greater than at the positive pole. The destruction of the tissues at the negative pole is heightened by the mechanical action of the liberated hydrogen-gas. In this connection it may be well to note that the scar at the negative pole is more pliable and less liable to produce cicatricial contraction than at the positive pole.

By virtue of the physical properties of the electricity when employed in electrolysis, we can limit the action to the surface of the skin by using metallic or carbon discs for electrodes, or can carry the action of the current into the deeper layers of the skin and even subcutaneous tissues with but little effect on the outer layer of the skin, provided the electrode is a needle and suitably insulated. The positive pole, when a needle, should always be of platinum, irido-platinum, or gold, because of the danger of the other metals, of which steel is a type, becoming oxidized and thus leaving an insoluble and colored compound in the skin, which may cause an indelible stain.

Electrolysis, while in the main a surgical procedure, has an element of the medical application of electricity, by virtue of the necessary transmission of the galvanic current through the tissues between the electrodes. Should the electrodes be placed near together and in such a manner that no important nerve-centres or trunks are traversed, the effects will be simply of a local nature, and, besides a slight increase in the volume of the part, an erythematous blush, and the sensation of heat, there is nothing worthy of mention.

Medical Therapeutics.

In surgical therapeutics we have had to do only with the galvanic current. In medical therapeutics we shall have to do with every form of electricity used in medicine. The classification of static, faradic, and galvanic is sufficient to include all the various forms of electricity without regard to the manner of their generation. Electricity, in whatever form it may be used, may, according to the mode of administration, act either as a stimulant, tonic, or sedative.

Static Electricity.—In this agent we possess one of the greatest stimulants to metabolism. It is doubtful whether either of the other forms of this force can compare with static electricity as a metabolite. The record which it has already made for itself well sustains these claims. Without doubt static electricity is the ideal cutaneous stimulant, and, while muscular contractions follow the use of the spark, the contraction is much less in proportion to the irritation of the sentient nerves than in any of the other forms of electricity. In practice it is found to be the rule that, the greater the tension, the greater the action on the sentient nerves.

The administration of static electricity by means of sparks is a most decided stimulant to the skin. At times the stimulation amounts to counter-irritation. This is frequently manifested by the appearance of wheals. At first sight one would imagine that the stimulant action was the only one that could be obtained from static electricity, but, when we find that neuralgias and other painful affections of the nerves of sensation yield to it, we are forcibly reminded that there is a sedative action as well. It is not always possible to draw a boundary-line between the stimulant and sedative action of electricity, and yet, by varying the mode of administration, we may obtain the desired result. For stimulation the spark should be used. For the sedative action the aura, or electric wind, and static insulation may be used.

Recently some experiments by the author have indicated that static electricity may be made to act as a sedative, by placing moistened electrodes on the surface of the body and interrupting the current from the discharging rods in metallic circuit by means of a Morton pistol-electrode, or, better, by means of the author's stationary modification of the same. The effect is similar, in its sedative action, to the rapidly-interrupted current of tension from a Tripier coil.

Faradic electricity, standing, as it does, midway between static and galvanic electricity, acts generally as a stimulant. It, however, can be made to act as a sedative, provided the current is derived from a coil wound with a considerable length of thin wire, and so rapidly interrupted that the sound produced by the commutator is a high-pitched musical tone.

Galvanic electricity acts as a stimulant under the following conditions: A strong current applied with moist electrodes rapidly carried over the surface. An interrupted or, better still, a frequently-reversed galvanic current with sufficient strength to be slightly painful, or to produce muscular contractions. A mild current applied continuously for a long time through fixed electrodes. In this latter instance the skin may be but slightly reddened, or there may be destruction of tissue due to the electrolytic action of the current. The sedative action of this current is usually obtained by the use of a mild current (not to exceed 3 milliampères) applied for a period not to exceed five minutes. Care should be used so that there should be no breaking of the current

in metallic circuit, in placing or removing the electrodes, or during the passage of the current.

From what has already been said in reference to the sedative action of the various forms of electricity, it will be noted that the exhaustion consequent upon the excessive or long-continued action of this agent is not included as a therapeutic sedative. It is doubtful whether this exhaustion is ever of any therapeutic value whatever.

As a counter-irritant galvanic electricity can be made to act promptly and efficiently, provided a sufficiently-strong current be used. In two instances I have seen a well-marked urticaria, which continued for several hours, make its appearance on the abdomen and occupy the space covered by the diffusion electrode, through which a current of 75 milliampères had been passing for from eight to ten minutes.

The metallic-brush electrode as an adjunct to the production of cutaneous stimulation, for both the faradic and galvanic currents, is of no mean importance. In the administration of the galvanic current it is well to bear in mind the electrotonic action of the poles, the negative pole producing the greatest amount of irritation followed by a diminution of irritability after the current is discontinued. The reverse is true of the positive pole.

Cataphoresis, or electric transfer, or osmosis, as it is variously termed, is a physical property of the galvanic current that has been taken advantage of in the endermic administration of remedies. If we desire to carry a metal, an alkali, or an alkaloid into the deep layers of or through the skin, then the covering of the positive electrode should be wetted with the solution and placed over the point where we wish the action of the medication. Should we desire the action of iodine or the acids on the deep tissues, then the covering of the negative pole should be wetted with the medicated solution. Should we use a solution of iodine or potassium on the positive electrode, we should not be deceived, by the discoloration of the skin and electrode, into believing that we are forcing iodine into the tissues, for we are not, but are getting a very superficial application of a weak solution of iodine in iodide of potassium.

Parasiticide.—Both static electricity and galvanic electricity possess the power to destroy many of the lower forms of organic life, and, when they make the skin their habitat, we possess in these agents a remedy that not only tends to destroy the parasite, but, at the same time, improves the nutrition of the skin, thus rendering the host a less hospitable one than he has formerly been. Static electricity has been given the credit of having cured two cases of the Guinea-worm.

Apparatus.

The following apparatus will be found to be of service in the treatment of the various forms of skin diseases :—

FOR THE GENERATION OF ELECTRICITY.

A reliable static machine. A faradic apparatus that will furnish a current of high tension with rapid interruptions. A galvanic battery of from 30 to 40 cells, or an apparatus for governing the current from an Edison dynamo. A battery of about 10 cells, with large surface of zinc opposed to a large electro-negative plate, for electrolysis.[1] A galvano-cautery battery, a storage battery, or an apparatus for controlling the commercial current so that it can be used with cautery electrodes, for galvano-cautery.

ACCESSORY APPARATUS.

A switch-board. A current-interrupter. A pole-changer, or current-reverser. A rheostat, or current-controller. A milliampèremeter, or current-measurer. Conducting cords. Universal electrode-handles. Needle-holding handles.

ELECTRODES.

A diffusion electrode of considerable surface. A metallic-brush electrode. Small metallic or carbon electrodes for application to a limited surface, or for the concentrated effect of one pole on the parts. An electrode for cataphoresis, either of carbon or one especially designed for the purpose. Needles for electrolysis, consisting of jewellers' broaches, thin cambric needles and irido-platinum needles, all ground pointed so as to be easy of introduction. Cautery electrodes of various forms to meet the various indications of ignipuncture, excision, or superficial searing. Static electrodes: the ball, for delivering or drawing sparks from the patient; the roller; the point, for producing the aura, or electric wind.

The above list includes nearly if not quite all of the apparatus for the electro-therapeutic treatment of skin diseases. It is not necessary to have all of the apparatus enumerated, to do good work in this line. As most physicians who attempt electro-therapeutics have nearly all of the articles enumerated, but few additions need be made to complete their outfit.

Cautions to be Observed in the Care of Electrodes, etc.—In no branch of electro-therapeutics do we find so much need for cleanliness and thorough antisepsis as in skin diseases. Lint, lintine, absorbent cotton or wool should take the place of the sponge as a covering to the electrodes. The electrodes should be thoroughly and frequently cleansed. All needles should be rendered aseptic. This is readily accomplished, in the case of the irido-platinum needles, by heating them in the flame of an alcohol-lamp or Bunsen burner. The steel needles

[1] While the ordinary galvanic battery used in medicine can be used for electrolysis, the battery fulfilling the indications above mentioned will give the best results. The Edison current has also been used, when properly controlled, for electrolysis, but the pain is usually so severe as to preclude its use.

may be kept in absolute alcohol, which not only destroys the germs, but, because of its freedom from water, prevents their rusting.

Before leaving this part of the subject we wish to emphasize one point, and that is, that you always know by recently-applied tests that your generators of electricity, conducting cords, and electrodes are capable of doing the work required of them. Remember that a single poor connection may cost you a patient.

Special Therapeutics.

The description of the various diseases of the skin will be taken up in alphabetical order. The nomenclature will be that found in the "Hand-Book of the Diagnosis and Treatment of Skin Diseases," by Arthur Van Harlingen, M.D. Each disease will be defined, and there will follow a description of the electrical treatment. For the symptoms, diagnosis, etiology, prognosis, and treatment, other than by electricity, you are respectfully referred to some of the standard works on diseases of the skin.

Acne is an inflammation of the sebaceous glands, usually of a chronic nature. It is manifested by the presence of papules, tubercles, pustules, or abscesses, which may appear alone or in combination. The seat of the disease is usually the face, neck, chest, or back. In papular, tubercular, and pustular acne, and in acne rosacea characterized by vivid redness, due to the enlargement of the capillary blood-vessels and later by the hypertrophy of the subcutaneous cellular tissue, we find that electricity is a useful adjuvant to other modes of treatment; in fact, in rosacea we can accomplish, by means of electricity, more than is possible by any other form of treatment. In papular acne, especially when accompanied by comedones, the plugs, which distend the glands and ducts, should be expressed before any application of electricity is made to the part. In pustular acne the contents of the pustule should be evacuated. In each instance the local and general treatment should be followed out according to the principles laid down in text-books on this subject. Galvanic electricity may be applied to the local lesion to accomplish the following: The positive pole applied over the lesion, sufficiently strong to produce a sensation of warmth or of smarting, will tend to relieve the congestion and remove the infiltration from the surrounding tissues. At first the tissue becomes reddened under the positive pole. The negative pole, applied in a like manner, will more markedly increase the congestion, but the ultimate results are essentially the same as when the positive pole is used. Should there be any solution of continuity, care must be taken, in the use of either pole, not to continue the current too long over the point of the lesion, for fear of producing an open sore and causing a scar. Where the lesion is inclined to be sluggish, without any tendency to resolution, the application of galvanic electricity aids very decidedly in quickening the processes. The greatest stimulating effect with the

galvanic current may be produced by alternating the current. The pole that is placed over the lesion should be first made positive, then negative, then positive again. Electrolysis is also of value in hastening resolution. The needle should consist of irido-platinum, which can be heated in a convenient alcohol-lamp so as to make it thoroughly aseptic before it is introduced into the follicle. This needle should be made the negative pole, and should be introduced into the gland, and the current carried sufficiently long to excite an inflammatory process. A slight amount of electrolysis will frequently dilate the entrance of the gland sufficiently to allow the contents to be readily expressed. At the same time, the lesion produced will tend to obliterate the gland.

Liebig and Rohé recommend in the torpid form of acne, in which there are many comedones and few pustules, that the dry faradic brush be applied to the diseased skin. Central galvanization and general faradization act as adjuvants, inasmuch as they are general tonics and tend to overcome the reflex irritation.

Acne Rosacea.—Electrolysis is a means of great value in the treatment of that form of acne rosacea in which the capillary blood-vessels are enlarged, either with or without hypertrophy of the subcutaneous cellular tissue. The especial apparatus for the treatment of these cases consists of a needle-holder and a thin needle, preferably a jeweller's broach pointed like a trocar or a hypodermatic-syringe needle. The patient is placed in a strong light and the positive pole, in a moistened electrode, is placed in the hand or on some other indifferent portion of the body. The negative pole, which is the thin needle, is so introduced as to traverse a portion of the dilated blood-vessel. If it is not found possible to thread the needle through the vessel, it is best to cause it to transfix the vessel in two or three places. A current from a galvanic battery of from 4 to 10 cells, with a strength of from 1 to 3 milliampères, is usually sufficient. The electrolysis should be continued until the walls of the blood-vessel are thoroughly destroyed, and when the needle is removed there should be no flow of blood through the vessel. If the vessel is simply transfixed in one place the lesion may be so slight as to cause no obliteration of the vessel, for, as the process of healing takes place, the vessel is found to re-establish itself. It is always best to select the prominent vessels in a given section, and attempt their destruction at one sitting, especially if they are found to be connected with a larger and deeper blood-vessel. During the electrolysis you can frequently see bubbles of hydrogen-gas liberated at the needle, carried into the blood-current, and at a point half an inch from the needle you may see the continuation of the vessel, outlined in white by the froth which fills it. This point will, as a general rule, be a desirable place to introduce the needle as soon as you remove it from its present position. The erythema which follows the application of electrolysis becomes, in a short time, so great that it obscures the vessels which were easily seen when the treatment was commenced. On this

account, and because of the sensitiveness of the part,—for the nose and cheeks are the parts usually affected,—it is best to terminate the sitting after a few electro-punctures have been made. The erythema soon disappears and a slight eschar temporarily marks the seat of the puncture. The ultimate results have, in many cases, proven exceedingly satisfactory. In the majority of these cases, it will be found best to have the patient complete the circuit by placing his hand on the sponge-electrode *after the needle has been introduced*, for the pain on introducing the needle is slight when there is no current passing through it. If, however, the hand is in contact with the electrode, the patient is very apt to flinch, thereby greatly increasing the difficulty of transfixing the vessels. After the vessels have been destroyed and there still remains an hypertrophy of the subcutaneous connective tissue, the needle may be carried well into this tissue and electrolysis induced there. This will gradually produce absorption of the hypertrophied tissue and thereby diminish the deformity. This treatment of rosacea is necessarily somewhat tedious, but the results produced are exceedingly gratifying to both physician and patient. A patient, sent to my clinic from the Department of Diseases of the Skin in the Chicago Polyclinic, was almost entirely relieved of a troublesome rosacea of the nose, much to the pleasure of the patient and, I think, surprise of the physician sending him. The patient was treated two or three times a week for six months.

Alopecia areata is an atrophic disease of the hair. It usually appears suddenly and manifests itself by the occurrence of one or more bald spots, which are usually circumscribed and variable in size and shape. The disease may consist of a single bald spot, or multiple bald spaces, even to complete baldness. This disease may be benefited by the use of electricity. The negative pole of a battery of from 4 to 10 cells should be applied to the bald spot sufficiently long to produce a redness of the surface of the skin. The faradic current is sometimes used alternately with the galvanic in the treatment of this disease. If the hair-roots are not dead, the stimulation produced aids materially in the restoration of the hair. In alopecia, electricity should be used only in connection with other remedies. If used alone you will probably be disappointed in it. In any form of alopecia in which the hair-roots are absolutely dead, no amount of electrical treatment will be of avail.

Anæsthesia is the converse of hyperæsthesia, as far as sensation is concerned, but is often dependent on the same pathological conditions. It will usually be most benefited by the stimulating applications as described under the head of "Hyperæsthesia."

Angioma is a disease of the skin consisting almost wholly of new-formed blood- or lymph- vessels. In case the growth consists of new-formed blood-vessels, we may classify it as belonging to one of the three following varieties: nævus vasculosus, telangiectasis, and angioma cavernosum. Nævus vasculosus, or birth-mark, consists either of one

or more spots, from the size of a small pin-head to one sufficiently large to cover the side of the face. The larger nævi are usually flat and level with the surface. Telangiectases are new growths similar to nævi which occur in adult life, and may consist of a single point, diffused patches, or linear ramifications of individual vessels, or a plexus of contorted capillaries. A marked case of this kind once came under my observation; the lesion was situated upon both cheeks of the patient, a young lady. At a little distance she had the appearance of constant and deep blushing. The contorted blood-vessels surrounded a pale centre. The blood-vessels were treated one at a time, and destroyed by means of electrolysis. After a few treatments the improvement was so striking that special attention was called to it by those who came in contact with her. Two years after the treatment the face was free from telangiectasis and there were no scars visible. Rosacea is a variety of telangiectasis. The treatment of telangiectasis is essentially the same as that described under the head of "Acne Rosacea." If, however, we have to deal with the first variety, it may be well to use an irido-platinum needle and make it the positive pole. Before removing the needle it is advisable to reverse the current and make the needle the negative pole for a short time, in order to free it from the dense and clinging coagulum produced at the positive pole. In reversing the current in these operations, it should always be borne in mind that the current should be gradually diminished before the reversal is made, otherwise the shock produced by reversing the current may be so severe as to give pain or cause some involuntary motion on the part of the patient sufficient to dislodge the needle. In nævus vasculosus and certain forms of telangiectasis the following method will be found to be the most useful: Two irido-platinum needles are introduced into the growth, usually parallel to each other. One is made the positive and the other the negative pole. The galvanic current is now gradually turned on until we have a strength of current of from 1 to 4 or 5 milliampères. When the destruction of tissue has been carried nearly far enough the current should be gradually discontinued, reversed, and then turned on again until the former strength has been reached. This procedure will render the removal of the positive needle much more easy. If the growth is of considerable size, repeated introductions of the needles may have to be made, either at this time or subsequently. Angioma cavernosum consists of a number of chambers partitioned off by a dense frame-work of newly-formed connective tissue. These chambers usually connect with each other and derive their blood-supply from some large blood-vessel in the vicinity. If the angioma cavernosum is not too large, it may be destroyed either by the galvano-cautery or by electrolysis. As a rule, a nævus of this character larger than one-half inch in diameter should be referred to the surgeon. When situated on the face or near the eye, electrolysis will be found of decided service. The main thing to be attained is the complete destruction of the vascular tissue, of which

these growths consist, and the ultimate shutting off of the blood-supply. Here the irido-platinum needles will be found of most service. The current is turned on until the blanching of the tissues and the appearance of the bloody froth around the point of entrance and exit of the negative pole give indications of the comparatively rapid destruction of the tissue. The current should be continued for such a length of time that when the needles are withdrawn very little or no hæmorrhage will take place. The attempt should be made to destroy as much of the growth in one sitting as, in the operator's opinion, it is justifiable to do. As soon as the lesion is healed, subsequent electrolysis should be performed until the desired results are obtained. The strength of the current will be governed largely by the power of endurance of the patient, the character of the growth, and the amount of tissue we wish to destroy. Before removing the needles, it would be well to throw off the current, reverse it, and then again pass the same strength of current through the needle as was originally used. By this means we shall loosen the positive needle from the coagulum which surrounds it. One great drawback in the use of electrolysis in the treatment of these growths is the pain, which, in some instances, becomes almost unbearable during the time of the electrolysis. It, however, possesses the following advantage: It is essentially aseptic, it is easily controlled, and the amount of destruction of the tissue is limited by the strength of the current and the duration of the application. If properly used, little or no hæmorrhage supervenes. The pain ceases almost instantly on the removal of the needle. In no operation do experience and judgment play a more important part than in electrolysis of nævi. The object to be attained is the destruction of the dilated vessels; hence a sufficient current must be used to completely destroy the capillaries, so that when healing takes place there will be no re-appearance of the vessels. (At the same time we must be careful to destroy as little of the superficial surface of the skin as possible, lest an unsightly scar follow.) Our efforts must be directed to produce cylinders of cicatricial tissue through the mass, so as to destroy the dilated vessels. If after this has been thoroughly done there still remain red points, these may be singled out one by one and destroyed by means of electrolysis. In nævi covering a large surface, several needles held in a holder so that they will be parallel to each other, yet separated one from another by about a tenth of an inch, may be used with advantage. The diffuse port-wine mark may be removed by using a needle inserted into the deeper layers of the skin and carried parallel with it, or by means of a number of needles so arranged as to make multiple electrolytic lesions. These needles may be inserted perpendicular to or at an angle with the skin. In either instance the result to be obtained is the production of scar-tissue, which will take the place of the unsightly colored area. In some instances the galvano-cautery is preferable to electrolysis · while the cautery destroys the tissues with

greater rapidity, it is more difficult to limit its action, and the scar produced is apt to be more marked than when electrolysis is used. The question as to which is best in a given case must depend upon the experience and judgment of the physician who employs it. If electrolysis is the means selected, the treatment may be applied at periods varying from daily applications to two weeks, according to the size of the nævus and the amount of tissue it is desired to destroy.

Anthrax.—See Carbuncle.

Atrophy of the skin is a disease characterized by a diminution either in the size or number of the tissue elements of which it is composed. While it may be limited to the skin or to the subcutaneous connective tissue, the muscles and even the underlying bones may be implicated. It may be idiopathic, or occur as a symptom in the course of or following various nervous, eruptive, or constitutional diseases. It is held by some to be due to injury or disease of the sympathetic nerve, and by others to be due to the influence of the trophic fibres of the trifacial or other nerves. Whether this disease is limited to the skin, or, as in hemiatrophia facialis, the subcutaneous tissue, the deeper tissues, and even the bones may be affected, the use of electricity promises more than any other means. The disease is, however, one that gives but little promise of relief. The following varieties of treatment, singly, in alternation, or in combination, may be employed. The galvanic current is employed in such a manner as to traverse the nerves distributed to the affected part, and also to stimulate the sympathetic ganglia of the neighborhood. Static electricity may be used to stimulate the tissues by means of the spark or the electrical aura or breeze. In connection with these it would be advisable, in case the muscles show atrophic changes, to faradize them, in order that, by means of this form of electrical massage, their volume and their maximum amount of contractility may be retained. Central galvanization and general faradization, in that they serve as general tonics and improve the nervous tone, may be used with advantage.

Baldness.—See Alopecia Areata.

Barbers' Itch.—See Tinea.

Boil.—See Furuncle.

Bromidrosis is a functional disorder of the sweat-glands. It is characterized by a marked and usually offensive odor exhaled by the skin. There is always more or less sweating accompanying this condition.

Hyperidrosis is a like disorder of the sweat-glands, characterized by an increased secretion of sweat. Static electricity has been found useful in the treatment of both of these affections by Shoemaker. He does not, however, give the method of treatment.

Callositas.—Callosities consist of an hypertrophy of the horny layer of the skin. They are of various sizes and shapes, of a firm consistence, and vary in color from being almost translucent to a gray, yellow, or

brown. They are usually caused by pressure, and are most frequently met with on the hands and feet. Both galvanic electricity and static electricity have been used in the treatment of the circumscribed varieties of this affection. The exciting cause should be removed in each instance, and other means employed as the exigencies of the case demand.

Cancer of the Skin.—See Epithelioma and Carcinoma.

Carbuncle is a phlegmonous inflammation of the skin and subcutaneous tissue which terminates in necrosis of the implicated structures. It differs from a boil in that it tends to spread at the periphery, and it usually has several openings, while the boil has but one. It is, without doubt, an infectious disease caused by the presence of a bacillus. The carbuncle differs from anthrax or malignant pustule in that the system is more profoundly affected with the poison in the latter disease. The local lesion is much the same in both diseases. The micro-organism of the anthrax is the bacillus anthracis. This disease is usually contracted by handling the skins, wool, hair, or bodies of some of the herbivora that have been affected with anthrax. Galvanic electricity has been successfully used to abort and cure carbuncles, boils, and other suppurative diseases of the skin and subcutaneous cellular tissue. To be of avail in these cases the disease must be taken at its incipiency. If the disease has reached a stage that it is impossible to abort it, then recourse may be had to the galvano-cautery to destroy the diseased tissue. If this is thoroughly done, the disease will be terminated, and we shall have but an open ulcer, which will heal by granulation. That this method is any better than curetting or excision I am not prepared to state. It has, however, been successfully used, and has one advantage in that it is thoroughly aseptic and is bloodless.

Cicatrices of the skin are new connective-tissue formations which take the place of lost normal tissue. There is a thin layer of epidermis, and the new tissue is supplied with blood-vessels and lymphatics. The hairs, sudoriparous and sebaceous glands which originally were present in the lost tissue are not reproduced. Scars are of a pale-red color, at first, but generally become white. Occasionally the scar may be pigmented. For our purpose, cicatrices may be divided into three classes: the hypertrophic, atrophic or depressed, and that variety in which the superficial vessels are dilated and resemble the non-hypertrophic form of telangiectasis. The hypertrophic variety, on account of its elevation above the surrounding surface, is more or less exposed to irritation, and, in consequence, is more apt to undergo degeneration, or, if upon the face, neck, or hands, it usually produces disfigurement. The treatment consists in their excision, when there is sufficient tissue in the neighborhood to allow of plastic surgery. If this is not possible, then much may be done by the use of massage or electro-massage (faradism), galvanic stimulation, and electrolysis. This latter will aid materially in the removal of the hardened and hypertrophic new formation. Atrophic

cicatrices, if not too numerous, can be treated with success by a careful, superficial cauterization by means of electrolysis. The needle, connected with the negative pole, should be introduced just below the superficial layer of the skin, and the current continued long enough to separate it from the underlying tissue. The needle should be re-inserted contiguous to the first point of insertion, and, in this manner, should be continued until the whole surface of the scar has been reached by the electrolytic action of the current. Our desire is to remove the superficial layer of the tissue covering the depressed scar, and when this is done the wound should be carefully dressed and kept impervious to the air by means of court-plaster or some like dressing. This dressing should be continuously applied until long after the time when we would remove it from any other portion of the body, for these scars are usually located on the face, and relief is sought on account of the disfiguration they produce. This long-continued application of the dressing tends to bring the depressed portion of the scar up to a level with the surrounding skin. If before, or even after, the lesion has been healed we see indications that the depression is not going to be obliterated, a fresh application of electrolysis and a continuation of the subsequent treatment will many times accomplish all that is desired. A similar result may be obtained by the use of a cantharidal collodion or some like substance which will remove the outer layer of the skin and produce a superficial sore. Subsequent treatment should be carried out in the manner described above. Electrolysis, however, is a preferable method, because we do not have to wait several hours before the superficial layer of the skin is removed, and we can limit its action much better than that of the other agents. The tediousness of the operation will prevent its being used, to any great extent, in multiple atrophic scars, as are found following a bad case of small-pox. The same treatment is also of value in those cases in which successive comedones have so dilated the orifices of the sebaceous glands as to produce comparatively large openings in the skin, which are apt to be continually filled with dust and similar foreign material, by reason of their size and depth. The cicatrices in which there are dilated blood-vessels may best be treated in the same manner as telangiectasis, described under the caption "Angioma." In case the scar is pigmented, the surface may be tattooed with a single or multiple electrolytic needle connected with the negative pole of the battery. In this case it is not absolutely necessary to remove all of the color, but rather to remove the large masses of color, leaving little points remaining so that, at a little distance from the patient, the scar will have the appearance of normal skin rather than the white appearance usually found in scars.

Carcinoma of the skin is a malignant disease of the skin and subcutaneous connective tissue, characterized by the infiltration of carcinomatous cell-masses into these tissues. Whether the carcinoma belongs to

either of the following three varieties,—carcinoma lenticulare, carcinoma tuberosum, carcinoma melanoides or pigmentodes,—it should be removed either by the cautery or by thorough electrolytic treatment. The last variety—carcinoma melanoides—frequently has its origin from a mole or wart on the face, hands, or feet. These moles or warts are usually deeply pigmented, and it is advisable to remove them before there is any thought of their taking on malignant growth. This can be readily done by transfixing the base with an electrolytic needle connected with the negative pole. After the tissue is destroyed for some distance around the needle, it should be removed and again introduced parallel to the original needle-puncture. Continue the treatment until a plane of tissue underlying the growth is completely destroyed by the galvano-caustic action of the current. It is not necessary that the growth should be removed. Within a day or two, provided the work has been thoroughly done, the tissue dries and forms a dense, brownish eschar, which serves as a protection to the granulating tissue beneath. After a few days this drops off, leaving a smooth and nearly healed surface. The same destruction of tissue may be accomplished by means of the galvano-cautery. The selection of one or other of these means will depend entirely upon the experience of the physician, the character and situation of the growth, and the apparatus at hand.

Charbon.—See Carbuncle.

Chilblain.—See Dermatitis.

Chloasma is a disease of the skin characterized by the deposition of pigment in the skin. It usually appears as one or more smooth, yellowish-brown, or blackish patches, of no definite form or size. They may be either idiopathic or symptomatic. Chloasma uterinum is a type of the latter. Shoemaker recommends the frequent application of the galvanic current as being one of the most suitable and efficacious means of removing the abnormal deposit of pigment in the skin. Some years ago I had a case of hypertrichosis situated in one of these pigmented areas. The removal of the hair was accompanied by the removal of the pigmentation for some distance around the point where electrolysis took place. This area of removal of the pigment was much larger than the slight scar usually produced by electrolytic epilation. A year or two afterward I had the pleasure of examining the patient again, and found that, while the pigmentation of the skin was essentially the same as when she was under my care, there had been no return of color at the seat of the removal of the hair.

Clavus, or *corn*, is a circumscribed callosity usually situated on the feet. It is cone-shaped, with the base presenting externally and the apex on the cutis. Daily applications of static or galvanic electricity to the corn have been found to be palliative, and in some instances a cure has resulted.

Comedo is a disease of the sebaceous glands characterized by the

retained and altered secretion. The skin surrounding the follicle is usually somewhat elevated above the surface. The orifice of the gland is generally marked by a blackish point, which is a mixture of the retained secretion and dirt. In the majority of cases the cause of the disease may be found to be dependent on dyspepsia, constipation, or of genital plethora or anæmia. Electricity may be of use in bringing about a healthy condition of the sebaceous glands. Of course, the gland-contents should be removed and the various recognized applications used. The dyspepsia and constipation should be corrected and proper means taken to remedy the condition of which the comedo is a symptom. In case the gland-contents cannot be readily removed, or there is a tendency to a low grade of inflammatory action, which does not go on to suppuration and consequent removal of the sebaceous plug, the electrolytic needle may be used with the expectation of stimulating the inflammatory processes. Static electricity has been found useful in stimulating the skin in this disease and in bringing about a healthy action. For further observations on the treatment of this condition see "Acne."

Cutaneous horns are hypertrophic growths of the epidermis, and, when fully developed, differ but little from horns found in the lower animals. The treatment consists in the removal of the growths, either by the knife or by twisting them off, and then cauterizing the base so as to prevent their reproduction. The galvano-cautery is an admirable means of accomplishing this result, provided the base is comparatively large. If of smaller area, electrolysis may be used with advantage.

Dermatalgia.—This disease is described by Van Harlingen as "an affection or rather condition of the skin characterized by the sensations of stinging, burning, darting, boring, or feeling as if the surface were raw. The suffering may vary from mere discomfort to agony." The surface of the skin may remain quite natural in appearance; light pressure causes pain; firm pressure frequently relieves the hyperæsthesia. "It has at times been called rheumatism of the skin. It is often a pure neuralgia, the result of anæmia, chlorosis, malaria, etc." The galvanic current has been found to afford relief in certain of these cases, and is best applied by placing one electrode—usually the negative—at some indifferent portion of the body, preferably on the back or near the spinal cord, and applying the positive pole over the hyperæsthetic area. The current should be sufficiently strong to produce the sensation of warmth or slight burning. The poles should be so arranged that the current should traverse the nerve-trunk leading to the hyperæsthetic part. If the disease is the result of anæmia or kindred affections, the medical treatment for such diseases should be employed. The benefits that are obtained from central galvanization and general faradization will serve as an adjuvant to the local and medical treatment. Static electricity may be used with advantage by administering sparks or the electrical aura or breeze.

Dermatitis is a general term for inflammation of the skin produced by means of some external agent acting on it; for instance, toxic substances, as poison-ivy, poison-oak, etc.; heat and cold, which are known respectively as dermatitis venenata, congelationis, and calorica. Galvanic and faradic electricities have both been used with good results in the treatment of the venenata and congelationis forms. Electricity gives relief not only by overcoming the local pain and irritation, but also by its influence in overcoming the inflammatory processes.

Dermatitis, Malignant Papillary.—This is sometimes called "Paget's disease of the nipple." It is actually a carcinoma, and should be treated as such. In its earlier stages it resembles eczema. The galvano-cautery or electrolysis may serve to arrest the disease in its incipiency, but, when it is once established, the complete excision of the part involved, even to the removal of the entire gland, should be done without delay.

Dermatolysis.—"Dermatolysis is a rare anomaly of the skin consisting in a more or less circumscribed hypertrophy of the cutaneous and subcutaneous structures, characterized by softness and looseness of the skin and a tendency to hang in folds." (Van Harlingen.) The affection is closely allied to elephantiasis. The treatment of the circumscribed form of the disease is removal by the knife, or galvano-cautery when practicable.

Eczema is an inflammatory disease of the skin. It may be either acute or chronic. At its commencement there may be present erythema, papules, tubercles or pustules, separately or in combination, accompanied by more or less infiltration and followed either by a discharge or with the formation of crusts or in desquamation. The eruption is attended by a smarting, itching, or burning sensation. Beard and Rockwell treated a case of eczema as early as 1872, by means of both the faradic and galvanic currents. Faradic electricity was first used locally over the seat of the lesion, with the effect to lessen the pain and relieve the itching. The relief was only temporary. Then they made use of central galvanization, without any application whatever to the local disease, with the result that a cure was produced. Their explanation was that the action of the galvanic current on the central nervous system improved peripheral nutrition. In chronic eczema when stimulation is needed, the negative pole of the galvanic current or the spark from the static machine serves admirably to bring this about.

Elephantiasis is a chronic hypertrophic disease of the skin and subcutaneous connective tissue, characterized by an increase in volume of the affected part, enlargement and deformity of the veins, inflammation of the lymphatics, œdema, thickening, induration, fissures, and warty growths. This disease is unquestionably parasitic. The parasite is a nematode worm known as the *Filaria sanguinis.* The female worm gains entrance to the body and locates itself in some of the lymph-spaces or vessels, and there extrudes its eggs, which, obstructing the smaller

lymph- and blood- vessels, form embolisms, which give rise to the lymphangeitis,—the most prominent symptom of this disease. As the young filariæ are of less diameter than the eggs, the inference is that the foregoing represents the true state of affairs. Mann has used galvanic electricity in one case successfully. He used a zinc-carbon battery of 16 cells. The negative pole was placed on the sole of the foot, while the positive pole, covered with a moistened sponge, was carried across the surface of the limb. The internal use of sulphide of calcium, given in divided doses so that the patient shall have from 3 to 6 grains daily, is advised because of its supposed ability to destroy the filariæ. Since 1877, Prof. Silva Araujo, of Rio de Janeiro, has treated upward of four hundred cases with electricity. His method of treatment is as follows: He makes use of electrolysis by introducing from one to three needles, insulated except at their points, into the tissues. The needles are made the negative pole and the positive pole is placed on the skin in the neighborhood. After ten minutes the needles are withdrawn and inserted in another place. Between the times of electrolysis, daily applications of the galvanic followed by the faradic current, of fifteen minutes' each, are made. In connection with this treatment he makes use of massage followed by the bandaging with the pure India-rubber bandage. A marked case of this disease, which was virtually cured, was under treatment for five years.

Epithelioma of the skin is a superficial, semi-malignant carcinoma involving the skin and also the mucous membrane at the orifices of the body. The new formation consists of epithelial cells in cell-nests, or processes of epithelial cell-formation projecting into the normal tissues. As a general rule, the complete extirpation of the epithelioma by means of excision should be employed when possible. By that means we are enabled to most thoroughly and efficiently remove the growth. There are situations, however, where a knife cannot be used with advantage, and where we have to select some form of caustic. In small and superficial epitheliomata, scraping with a dermal curette or sharp spoon, followed by the application of the galvano-cautery, is of advantage. In operations in the neighborhood of the eye, the galvano-cautery has done good work. In fact, in any case where the actual destruction of tissue is desired, probably no better cautery can be selected than this, because of the ease of manipulation, the amount of tissue that can be destroyed, and the slight pain connected with the cauterization as compared with that of many of the chemical caustics. The sealing of the blood-vessels and the comparative freedom from pain which follows its use are two points which commend it to the consideration of the operator.

Equina.—See Glanders.

Erysipelas is an acute inflammation of the skin, caused by the invasion of a specific micro-organism known as the streptococcus erysipelatus. The disease is characterized by a sharply-defined area of redness, which gradually advances so as to occupy a larger surface as the disease

advances. There is, at the same time, a relatively intense febrile systemic disturbance. When the disease terminates in recovery there is an exfoliation of the epidermis covering the seat of the disease. Erysipelas may be checked by the application of galvanic electricity. The positive pole is applied to the lesion by means of a moistened electrode; the negative is applied by a like electrode to the periphery of the affected area.

Farcy.—See Glanders.

Favus.—See Tinea.

Fibroma molluscum is a new growth of the connective tissue characterized by the development in the skin of firm or soft, painless, sessile, or pedunculated tumors of varying size. The treatment consists in their removal. The galvano-cautery is the best means of treatment of the pedunculated variety, or even of the sessile form, when they are so situated that the galvano-cautery loop can be thrown around them without too much destruction of tissue. Electrolysis of the less-prominent varieties may also be tried with the hope of bringing about resolution.

Filaria Medinensis, or Guinea-Worm Disease.—This disease, which is exceedingly rare in this country, has been cured by means of both galvanic and static electricity. Dr. Van Harlingen speaks of a case in which success attended the application of the galvanic current. One of the poles of the battery was placed on the head of the worm and the other was held by the patient. Shoemaker speaks of two instances in which the parasite was destroyed by the aid of static electricity. Alexander Faulkner, in the *British Medical Journal*, 1883, describes the removal of this parasite by means of the galvanic current. One pole was held in the hand and the other was placed on the protruding extremity of the worm. The current was continued for an hour; in the meantime, gentle traction was made on the worm till it was extracted. In this manner one treatment was able to accomplish that which usually takes weeks to do. It seems that the electricity benumbed the worm so that it ceased to resist.

Freckle.—See Lentigo.

Furuncle, or *boil*, is a circumscribed inflammation surrounding a gland or follicle of the skin. The follicle is ordinarily the point of entrance of the microscopic germ that causes the inflammation, which usually terminates in necrosis of the tissue, with the expulsion of a central slough or core. If the case is in its incipiency, it is possible to abort it by the continuous application of the galvanic current. Dr. Tuholske, according to Hardaway, recommends the introduction of the electrolytic needle as being efficient in aborting boils. After the inflammation has reached the point where it is impossible to cause resolution, the same treatment that is used for carbuncle may be employed, but such heroic measures are not usually called for.

Glanders, or *farcy*, or *equina*, is a malignant contagious disease derived from the horse. Electricity will be of service only in the local

treatment. By means of it we may be able to locally destroy the virus by thorough cauterization of each ulcer. Ulcers occurring in the nostrils can be reached by means of the various electrodes used by rhinologists. Of course, the general treatment must not be neglected, full descriptions of which will be found in works on skin diseases.

Guinea-Worm Disease.—See Filaria Medinensis.

Hemiatrophia Facialis.—See Atrophy of the Skin.

Herpes is an acute inflammatory disease of the skin in which there are one or more clusters of vesicles situated upon a somewhat reddened base. The disease is non-contagious.

Herpes simplex, formerly known as herpes labialis or herpes facialis. Some writers claim that this may be aborted in its early stage by the continued application of the mild galvanic current, one pole being placed over the seat of the lesion.

Herpes Zoster.—In this variety the eruption is situated over the course of some superficial nerve. It is usually accompanied by some febrile manifestation, and there are more or less neuralgic pains, which may persist even after the skin-lesion has disappeared. Galvanic electricity has been found of use in this disease, more especially because it relieves the neuralgic pains. A current of from 5 to 10 cells may be used, the positive pole applied over the course of the nerve, the negative near its origin. Applications may be made once or twice per day and continued fifteen or twenty minutes at a sitting. This current is also of service in removing the neuralgic pains which frequently follow the eruptive stage.

Horn, Cutaneous.—See Cornu Cutaneum.

Hyperidrosis.—See Bromidrosis.

Hyperæsthesia of the skin is a morbidly acute sensitiveness of the skin to external influences. It may be general or local, diffused or circumscribed, unilateral or symmetrical. The temperature, as a rule, remains normal. It may be symptomatic, but is generally idiopathic. Electricity, in the various forms used in medicine, has been used in hyperæsthesia with success. As a rule, the sedative applications will be found to be the most serviceable, the application of a mild galvanic current, static insulation, and breeze belonging to this category. In case improvement does not follow this treatment, the stimulating application of electricity should be tried. The following are some of the best methods for using the various forms of electricity for this purpose: The application of the galvanic current should be of sufficient strength to produce a decided impression on the skin. The negative pole should be the one chosen for application to the affected part, and may be applied by means of a moistened electrode or a metallic brush. The faradic current may also be used, preferably by means of a brush or flat carbon disc. The administration of sparks from the static machine is a stimulant of decided value. In the symptomatic form of hyperæsthesia, the

disease of which it is a symptom should receive its appropriate treatment, and the local treatment should be governed by the requirements of the primary disease. See "Dermatalgia."

Ichthyosis is a congenital, hypertrophic disease of the skin characterized by a partial or general thickening of the epidermis, together with more or less elongation of the papillæ. The skin is dry, harsh, or scaly. In the variety known as ichthyosis hystrix, the ill-defined, yellowish, brownish, or greenish patches are made up of enormously hypertrophied horny papillæ. In this variety the horny and warty growths may be removed by means of the galvano-cautery. I have failed to find mention of any other use of electricity in this acknowledgedly incurable disease, but it is more than probable that, in the near future, the beneficial action of other applications of electricity will be recognized.

Keloid is a new growth of the connective tissue characterized by one or more irregular, elevated, firm, somewhat elastic, pale-red, cicatriform lesions. The growths vary in size from that of a split-pea to a cocoa-nut. Dr. W. A. Hardaway, of St. Louis, and Dr. L. Brocq, of Paris, and others report successful cases following the treatment by means of electrolysis. Others report success in the removal of scars that have undergone keloid degeneration, but have failed in the treatment of the true keloids. Hardaway directs that "A stout needle attached to the negative pole of the galvanic battery should be used, and the punctures should be made from side to side, and perpendicularly through the body of the growth. In addition, on anatomical grounds, I should suggest that the needle be plunged into the tissues for quite a space around the tumor, so as to destroy the diseased vessels going to it." From the conflicting reports in reference to the benefits of electrolysis it can only be said that this treatment is still on trial. It is questionable whether electrolysis will be of advantage in cases in which the growth has attained any considerable size. A recent article describes a case of keloid of the lip following the electrolytic removal of the hair. The operator was unsuccessful in removing it by electrolysis.

Lentigo, or Freckles.—For very black freckles Dr. W. A. Hardaway recommends that each freckle be touched with the negative electrolytic needle. Care should be taken that the needle does not penetrate to the deeper layers of the skin, thereby causing a scar. This process may be termed a species of tattooing. Local applications of galvanic electricity, frequently repeated, have been employed with most decided benefit.

Lichen is a dry, papular, or papulo-squamous disease of the skin. The two forms of the disease with which we have to do are known as lichen planus and lichen ruber. Some authorities consider that they are the same disease, while others classify them as two distinct and separate diseases. Shoemaker classifies the lichen planus among the exudations and states that it is inflammatory, while he places lichen ruber among the hypertrophies and says that it is non-inflammatory.

The prognosis of lichen planus is always favorable, while that of lichen ruber should be decidedly guarded. Lichen planus is characterized by the formation of small, flat, circular or quadrangular, reddish, umbilicated papules. The course of the disease is chronic, and resolution is followed by pigmentation of the surface. Lichen ruber is characterized by the development of a number of small, firm, red papules, which do not increase in size, but manifest a tendency to become chronic. There is frequently considerable itching and constitutional disturbance. In some cases this disease appears to be the initial manifestation of general debility, marasmus, and death. As both forms of the disease are in a measure neurotic in their origin, spinal or central galvanization should give relief. The reported cases in which electricity has been tried, however, have not justified our expectations. Electric baths and static electricity deserve a trial, as they act as general tonics and also have a local action on the skin.

Lupus erythematosus is a superficial inflammatory affection of the skin characterized by very slow development, and by the production of atrophy or cicatrization without ulceration. The disease appears as one or more circumscribed, roundish or irregularly-shaped, variously-sized, reddish patches, covered with grayish or yellowish adherent scales. Erythematous or telangiectatic lesions may also be present. The galvano-cautery has sometimes been used with success in this disease. It has been found that the superficial searing of the tissues with a galvano-cautery electrode, of large size and heated barely red, is advantageous. The surface is covered with iodoform or some like antiseptic dressing, and after ten or twelve days the eschar separates, leaving a pale, smooth surface. The telangiectatic variety may be treated the same as telangiectasis, under "Angioma."

Lupus vulgaris is a very chronic, new cell-growth, appearing in the form of variously sized and shaped, reddish or brownish spots, consisting of papules, tubercles, or flat infiltrations, usually terminating in ulceration or cicatrization, although they may undergo interstitial absorption. This disease is, in all probability, caused by the infection of the skin with the bacillus tuberculosis. The complete destruction of this lesion may be attempted by the galvano-cautery. If the surface is small, it may not be necessary to place the patient under the influence of an anæsthetic, as the pain is not usually so severe but that it can be borne by the patient. If, however, it should be thought necessary to use either a general or local anæsthetic, great care must be used to prevent the ignition of the ether or rhigolene. There is considerable inflammatory action following the operation. Under the application of water dressings this soon subsides. All of the lupous tissue may be destroyed at one sitting, but it will be found, ordinarily, that the operation requires to be repeated. Brocq, of Paris, prefers either a combination or alternation of scarification and cauterization. For the latter he gives preference to the galvano-cautery.

Milium.—Milia are those small, rounded, whitish or pearly, non-inflammatory elevations which are situated on the face, usually near the outer canthus of the eye, and are covered by a thin layer of epidermis. The contents are similar to those of the comedone, and, in reality, milia are superficial glands the orifices of which have become closed. Ordinarily it is sufficient to open each one of these and express the contents. Should they recur, the glandular tissue may be cauterized so as to prevent the secretion forming. This may be done by means of a comparatively coarse cambric needle which has been broken off and the point ground spherical in shape. This needle, connected with the negative pole of from 3 to 10 cells of a battery, is introduced through the opening made for the removal of the contents, and the current carried sufficiently long to destroy the secreting surface. Dr. W. A. Hardaway originally suggested the employment of electrolysis for this disease.

Mole, Pigmentary.—See Nævus Pigmentosus.

Molluscum epitheliale, or *molluscum contagiosum*, as it is also known, is a disease of the upper layer of the skin characterized by small, superficial, whitish tumors. They may occur singly or in groups. They have a smooth, semi-globular, umbilicated appearance, and yield, on pressure, a soft, whitish, greasy, consistent body or a semi-fluid substance resembling sebum. The treatment consists in removing the contents of the tumors and cauterizing the cavity. Both Hardaway and Rohé recommend the use of electrolysis in the treatment of these cases. In fact, either electrolysis or the galvano-cautery will serve as the caustic. The galvano-cautery will hardly be required in most cases, but occasionally it may prove the most speedy and, at the same time, most efficacious means to use.

Molluscum Fibrosum.—See Fibroma Molluscum.

Morphœa is a form of scleroderma characterized by one or more well-defined patches on a level with, or slightly depressed below, the surface of the skin, and surrounded by a bluish, rose-colored, or lilac border. The patches may be either white or discolored from a deposit of pigment. Localized galvanization, in combination with massage and the local application of some of the mercurial preparations, is recommended by Shoemaker as being of service. Hardaway claims to have treated a number of cases of this disease with galvanic electricity, but without benefit.

Mother's Mark.—See Angioma.

Nævus.—See Angioma.

Nævus lipomatoides is a name given to the thick, soft, connective-tissue growths of variable dimensions. If large and pedunculated, they may be removed by means of the cautery wire. Otherwise, electrolysis may be employed with a decided degree of success.

Nævus pigmentosus, or *pigmentary mole*, consists of a circumscribed pigmentary deposit in the skin, varying in color from a light brown to a jet black. The nævus may be with or without hypertrophy of the skin

and subcutaneous connective tissue and appendages. This form of nævus consists almost entirely of a deposition of pigment in the deeper layers of the skin, without any special increase in the growth of the skin or contiguous structures. The object is to remove the coloration without producing an unsightly scar or atrophy of the tissue. This can be best done by multiple punctures of the nævus with the electrolytic needle connected with the negative pole. The punctures or tattooing should be close enough together so that, when the lesion produced by the electrolysis is healed, there is only a small amount of tissue between the punctures, and that when the scar-tissue, which at first is red, has, after a few weeks, become white, the appearance of this part is, at a little distance, like the surrounding tissue.

Nævus Pilosus, or Hairy Nævus.—In this form of nævus, the first effort should consist in the removal of the hairs scattered over the surface. Each hair should be removed, and a sufficient time should be allowed to elapse, before other treatment be attempted, to demonstrate that the hair is effectually destroyed. As the hairs in this growth are usually coarse, with the root deeply situated in the tissues, they are rather more difficult to remove than hairs found on other portions of the face and body. As we usually desire to remove a certain amount of pigment or destroy some of the connective tissue which gives volume to the mole, we can use the current stronger, and for a longer time, than we would ordinarily do if we were using it to remove the hairs alone. Frequently this accomplishes all that we desire in the case; but should there still remain a decided prominence, the growth may be subsequently removed by means of electrolysis or the cautery loop. If the hair is not previously removed, we are apt to have a growth of hair through the cicatricial tissue, which will be exceedingly difficult of removal, and therefore make our operations much more tedious and unsatisfactory.

Nævus verrucosus, or *warty nævus*, is a term used when the nævus is rough or uneven. This warty-like growth may be removed by means of the electrolytic needle carried under the surface of the nævus, parallel to the skin. If of considerable size, it may require several sittings to remove it.

Nettle-Rash.—See Urticaria.

Neuralgia of the Skin.—See Dermatalgia.

Noli me Tangere.—See Lupus Vulgaris.

Paget's Disease of the Nipple.—See Dermatitis, Malignant Papillary.

Pruritus is a neurosis of the skin which manifests itself by either tingling, burning, creeping, or pricking sensations. There is no structural alteration of the skin. It may be idiopathic or symptomatic, or due to some external irritant. Galvanic, static, and faradic electricities have all been made use of in this affection, and each form has proven efficacious in giving temporary relief. As we desire to influence the nerve-terminals, our treatment should be directed to the skin at the seat

of the trouble. In case galvanic electricity is chosen, the current should be of such strength as to produce a sensation of warmth under the electrode; but should faradic electricity be selected, a current from a helix made of thin wire, with exceedingly rapid vibrations of the rheotome, will afford the best results. The current may be applied either by means of a brush or moistened electrode. Static electricity administered by sparks, the electric breeze, or the static electric bath is of advantage when the pruritus is a symptom of senile or other changes in the skin; this form of electricity is also a means of keeping the formication accompanying central nervous disease in abeyance. If the pruritus is symptomatic the cause should be removed if possible, and, in certain cases, electricity may be the very best means at hand, especially if the primary disease is one of the nervous system. When due to some external cause, the pruritus may remain for some time after the cause has been removed. In this case, electricity gives prompt relief.

Psoriasis is an inflammatory disease of the skin characterized by an outgrowth of the epithelial layers of the skin. The lesions are slightly elevated, round, and reddened, of various sizes, and covered with dry, white or mother-of-pearl colored, imbricated scales. Galvanic and faradic electricities have been repeatedly tried in this disease, but the reported successes have been very few in number. Shoemaker says, "I have repeatedly observed good results from franklinism, especially where infiltration has occurred, and there is obstruction to the local circulation by inflammatory deposits, which are speedily caused to be absorbed by these applications."

Purpura is a disease of the skin which consists in the formation of hæmorrhagic patches in the skin, with or without elevation above the surface, and which do not disappear on pressure. The hæmorrhages may be of different sizes and shapes. Purpura hæmorrhagica includes a group of cases that have one symptom in common,—that is, the eruption of the skin is accompanied by hæmorrhages from the cavities of the body. Mr. Shand, of Glasgow, reports a case of this disease in which, as a last resort, faradic electricity was applied by carrying the moistened electrodes over the whole surface of the body. The treatment was repeated at intervals of two hours. Little or no hæmorrhage took place after the application of electricity was instituted, and the patient made a good recovery. The beneficial action of electricity, in this case, was supposed to be due to its tonic action on the nervous system, and the action on the capillaries through the vasomotor system.

Ringworm.—See Tinea.

Rodent Ulcer.—See Epithelioma.

Sarcoma of the skin is a malignant disease of the skin characterized by the deposition of sarcomatous material in the skin and subcutaneous connective tissue. The treatment by electricity is the same as described under the heads of "Epithelioma" and "Carcinoma of the Skin."

Scars.—See Cicatrices.

Scleroderma is an affection of the skin characterized by a diffuse or circumscribed, pigmented, indurated, and hide-bound condition of the skin. Schwimmer reports success in a case of generalized scleroderma after eighteen months' treatment by subaural galvanization.

Scrofuloderma is the name given to a number of skin diseases dependent on that condition of the system known as scrofulosis. Some of the scrofuloderms are difficult to differentiate from syphiloderms and lupus vulgaris. Others resemble tuberculosis of the skin and superficial lymphatic glands. For an extended description of the scrofulous diseases of the skin, see some of the standard works on the subject. Shoemaker says that "roughness of the skin in scrofuloderma is, in a great measure, remedied by thorough franklinization, while there is noted a general systemic tonic effect." This same author has also seen marked good results follow the judicious use of faradism, either alone or in combination with galvanic electricity.

Seborrhœa is a functional disease of the sebaceous glands of the skin, characterized by an altered and increased sebaceous secretion and a consequent forming of an oily coating, crusts, or scales on the skin. Piffard has used galvanic electricity with advantage, in the treatment of seborrhœa oleosa.

Shingles.—See Herpes.

Sweating, Excessive.—See Hyperidrosis, under Bromidrosis.

Syphilis of the Skin.—The initial lesion has at times been cauterized with the galvano-cautery, and, while it may stimulate the chancre to become a healthy ulcer, I doubt whether it has ever destroyed the virus, especially that which has been carried into the tissue beyond the reach of the galvano-cautery wire. It is not necessary here to go into any lengthy controversy on this point, as that which has been written in standard works on this subject, in reference to excision, will apply to the use of the galvano-cautery. I do not know that cataphoresis has ever been used in the treatment of chancre, yet it is quite probable that excellent results may be obtained by the forcing of soluble mercurial salts into the tissues by this means. The positive pole of the galvanic current should be moistened with a soluble mercurial, and then be brought directly into contact with the lesion. In this way we may succeed in thoroughly saturating the tissues with mercury, and thus change the character of the ulcer for the better. In many of the secondary forms of syphilitic eruptions, especially the papular, tubercular, and gummatous varieties, the cataphoric action of the current may be resorted to with decided benefit, particularly when the eruption is upon the face or neck, and is marked by the appearance of that peculiar color characteristic of syphilitic eruptions. The positive electrode should be covered with several thicknesses of filter-paper, or some like absorbent material, and freshly saturated with a solution of some soluble mercurial, cor-

rosive sublimate being a type. The strength of the solution may vary from one in a hundred to one in three or four thousand. This is now placed over the syphilitic eruption, and the current turned on until of sufficient strength to cause a very decided tingling or stinging sensation, if not absolute pain. Each point must be subjected to this treatment. It would be well to prepare the skin for the operation of the remedy in question by having it thoroughly washed with soap and water, and afterward bathed with alcohol or ether to remove as much as possible of the natural oil from the surface of the skin, as this would tend to prevent the introduction of the medication. Of course, this treatment is only supplemental to a thorough constitutional treatment, which should not be neglected by any means. Cataphoresis aids materially in quickening the process and in removing the tell-tale color. As the rapid cure of the syphiloderm is, at times, a matter of vital consequence to the patient, this means of rapid removal of the blemish is of decided value to the physician.

Tinea.—The different varieties of tinea are produced by vegetable parasites, which make the skin, the hair-roots, and other appendages their habitat. In tinea versicolor the microscopic plant is named *Microsporon furfur;* in tinea favosa the parasite is named *Achorion Schönleinii;* in tinea tricophytina the microscopic fungus is *tricophyton.* In the various forms of this disease the cataphoretic action of electricity is made use of for the purpose of conveying medicinal substances, usually of a parasiticidal nature, into the deeper layers of the skin, where these parasites make their habitat. The strength of the current should be all that the patient is able to bear. This will be found to vary in different cases, and, in all probability, when the current has reached a strength of 8 milliampères, the limit of endurance will have been reached. The negative electrode should be placed on some indifferent portion of the skin, and should be of a comparatively large surface. The electrodes should be so placed that the current, in traversing the tissue between them, should not traverse any of the larger nerve-centres or important nerves. The following quotations are from an article by H. J. Reynolds, M.D., of Chicago, read before the Section on Dermatology, Ninth International Congress, entitled "A New Method in the Treatment of the Vegetable Parasitic Diseases of the Skin": "Tinea favosa, tinea versicolor, and the three forms of tinea tricophytina are amenable to this treatment." "The surface to be treated should first be cleansed of crusts, scales, and sebaceous matter by the usual process of oiling and washing with soap and hot water, etc. If thought necessary, of course, the loose hairs may be removed, though in the cases I have treated this has not been done. I saturate the sponge of the positive electrode with whatever parasitical lotion is preferred, which may be aqueous, alcoholic, or ethereal, and place it directly upon the part to be treated. I then place the negative electrode, well saturated with water, on some point

near by. A more remote point, as the hand, for instance, will answer, but it will take a longer time to get the same effect than when placed near by. The electrodes should be kept firmly pressed to the skin, the positive being occasionally moistened, as required, with more of the solution, and the negative with more water. In order to get a sufficient effect, the electrode should remain on each place several minutes before applying it to another place on the scalp. I think it is not wise to continue the treatment over ten or fifteen minutes in all at each sitting, and perhaps not oftener than once a day. The parasiticide used in the case I treated was a 1-per-cent. solution of bichloride of mercury." This method of treatment has been recognized in Europe, and employed by Drs. E. Charon and G. Gevaert, of Brussels. The sublimate solution which they used was not stronger than from three to five per thousand. The following observations by these gentlemen will be of interest to those who desire to use this valuable means of treating these troublesome diseases: "We have observed, particularly in sensitive patients, that the contact of the anode (positive pole), even with a weak solution (as a three per thousand), called forth cries of pain during the sitting, producing a sensation of painful pricking, which must be incontestably attributed to the penetrating action of the mercurial salt. In operating we use a sulphate-of-copper battery of only twenty elements, and never have we produced, with current of this strength, painful impressions in treating chronic nervous affections, where the positive pole is not impregnated with medicinal agents. On the other hand, a three-per-thousand solution of corrosive sublimate applied by friction is not capable, in a child, of producing painful sensations. We have here, then, positive proof that the painful tingling analogous to that produced by a scald must depend on the combined action of the mercurial salt and the galvanic current. We have, therefore, at our disposal a powerful medium, capable of carrying to the interior of the hair-sheath an energetic parasiticide."

Tattoo-marks consist of an insoluble pigment introduced under the surface of the skin, which leaves an indelible stain. These marks may be removed by means of electrolysis. A sharp-pointed needle should be connected with the negative pole of a galvanic battery of from 3 to 10 cells, and carried into the skin sufficiently deep to reach the pigment and excite sufficient inflammation to cause it to be thrown off. The positive pole should be placed in the hand or on some indifferent portion of the body.

Telangiectasis.—See Angioma.

Tumors, *Erectile.*—See Angioma.

Ulcer, *Chronic.*—Chronic ulcers are open, suppurating sores, of various shapes and sizes, extending to different depths, and which partake of all the phenomena of inflammation. As early as 1848 Sir Spencer Wells called attention to the fact that if a simple galvanic couple,

made of a piece of zinc and of silver connected by means of wire, were placed on an ulcer, the ulcer tended to heal under the silver plate and became worse under the zinc plate. In this connection, it may be well to mention the fact that if the two poles of a galvanic battery are placed on the surface of the body, and retained there for some time, no matter how weak the current may be, a solution of continuity will take place and an ulcer be produced at the point of contact of each pole. The eschar at the negative pole will be the deepest and most extensive. Ulcers may be stimulated to assume a healthy condition by the application of the galvano-cautery to the indurated edges; also, by a superficial searing of the surface by means of the flat knife or disc-like electrode, heated to a dull red. The galvanic current has been used with advantage, by taking a zinc electrode, connected with the negative pole, of sufficient size to cover the ulcer, and placing it over the lesion; the positive should be placed on some indifferent portion of the body. If a feeble current of from $\frac{1}{2}$ to 1 milliampère is used, the application should be continued for from thirty minutes to two hours. If a stronger current is used, a less time should be occupied in the treatment of the case. This treatment can be repeated as often as it is necessary to stimulate the unhealthy surface of the ulcer. Rest, cleanliness, stimulating and emollient dressings should be combined with the use of electricity to get the best results. The cataphoric action of electricity, to drive a weak solution of corrosive sublimate into the tissues, has been made use of with success in the stimulating of indolent ulcers.

Urticaria is a mild inflammatory disease of the skin characterized by the sudden development of wheals of a whitish or reddish color, accompanied by stinging, pricking, itching, and tingling sensations. The wheals are ephemeral in character. The itching of this disease may be relieved by the use of faradic electricity, commencing with a mild current applied over the seat of the lesion, gradually increasing the strength until the patient is unable to bear the current any stronger. If the urticaria is due to some error of diet, or to some intestinal irritation, the usual means for correcting these irregularities should be employed. In this disease faradization acts as a palliative, not a curative agent. See also "Pruritus."

Verruca, or *wart*, is a hypertrophy of one or more cutaneous papillæ. These growths are of various shapes, sizes, and densities, but always circumscribed elevations. Static and galvanic electricities have both been found of use in the treatment of this disease. The static may be applied by means of sparks, made to traverse the hypertrophied tissue. This may be accomplished by applying a metallic rod or conductor directly to the wart. This conductor should terminate at one end in a ball, and the spark should be delivered to it from the static machine. The action of the static electricity may be explained, in part, on two grounds: one, that it is a parasiticide; and the other, that by increasing

the tissue-metabolism it improves the nutrition of the part, thus rendering the tissue a less-hospitable host to the bacillus which makes the skin its habitat, and on the irritation of which the existence of the wart is dependent. The galvanic current may be used, applied directly to the wart and allowed to pass through the tissue for some length of time; or, if the wart is raised above the surface of the skin, electrolysis may be used to cause the destruction of the underlying tissue. The needle should be made to enter at the junction where the normal surface of the skin ends and the wart commences to raise itself above the surface. Parallel and transverse introductions of the needle should follow until a plain of dead tissue results, thus effectually cutting off the blood-supply to the wart. In case the growth is not raised above the surface of the skin to any great extent, the needle may be carried vertically into the tissue, thus destroying the abnormal growth. In the vascular variety, and especially in venereal warts, the galvano-cautery will be found to be of decided service, in that it is quick in application, prevents hæmorrhage, and is attended with little pain, either at the time of operation or subsequently.

Vitiligo is an acquired disease of the skin in which there are one or more sharply-defined, smooth, white patches developed. These patches tend to constantly increase in size. They are usually surrounded by an abnormally yellowish or dark-pigmented skin. Galvanic electricity is of advantage in removing the pigmentation surrounding the white patches, thus rendering the deformity less marked. The negative pole attached to a moistened electrode should be the one selected for the local application. As the result to be obtained is the removal of the pigment, the current should be of nearly, if not quite, sufficient strength to blister.

Wart.—See Verruca.

Wounds.—(Needle-pricks, cuts, abrasions of the surface.) These may be readily determined by placing one hand in a basin of water in which one of the poles of the galvanic battery is placed. The other pole is taken in the free hand, and if there is any solution of continuity it will at once manifest itself by a smarting and burning sensation peculiar to the galvanic current. In this way, needle-pricks that cannot be seen can readily be located. It is advisable, for physicians in particular, whenever they are about to perform some surgical operation, especially when the patient is syphilitic or one that has suppurating or infected discharges or accumulations, that this test be made, in order that the hands be so thoroughly prepared that they will present no points for infection.

Xanthoma is a connective-tissue new growth, consisting of yellowish patches, from the size of a pea upward, either flat and level with the skin or in mulberry-like or raised masses. It is usually found on the eyelids. Dr. Wende, of Buffalo, has succeeded in removing these growths by means of electrolysis.

Zoster Zona.—See Herpes Zoster.

Concluding Remarks.

In the early seventies Beard and Rockwell made use of both galvanic and faradic electricity in the treatment of the following skin diseases: eczema, anæsthesia, acne, acne rosacea, psoriasis, herpes, tinea circinata, and elephantiasis. In some of these diseases the success was marked and in others it was problematical. In 1878 Dr. Hardaway, of St. Louis, reported a case of superfluous hairs removed by means of electrolysis. He was thus the originator of this process, that has since that time become a recognized and efficient means of relief, in this class of cases. In 1879 he advocated the use of electrolysis in the treatment of acne rosacea and telangiectasis. Since that time various other specialists in skin diseases have made use of this agent; prominent among this number may be mentioned Hardaway, Piffard, Fox, Reynolds, Van Harlingen, and Shoemaker. Gradually the scope of electricity has been recognized and the field of its application enlarged, until to-day there can hardly be found a specialist on the skin who has not a suitable electrical apparatus for treating the various cases in which this agent may be of benefit. It is not necessary to enter into all of the causes which have brought this about, but before we leave the subject one or two may be mentioned, viz., that the physicians are, as a general rule, better posted on the subject of electro-therapeutics than they were even five years ago; again, the investigations that have been instituted have brought out the indications for the use of electricity and have better defined its limitations. We have not yet accomplished all that may be possible with this agent, and in the near future we may look for a more-extended application in this special line.

DISEASES OF THE NOSE, NASO-PHARYNX, PHARYNX, AND LARYNX.

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Were this article to be limited to the methods bringing electricity into direct use as a therapeutic agent, it would indeed occupy but little space. A few hints concerning its value as a disintegrator of growths and as a stimulant in the atrophic forms of rhinitis and pharyngitis, and in the laryngeal neuroses, would represent about all that could be said about this agent. To account for this is not difficult. Sufficiently within reach to render the use of surgical appliances and direct medication possible, the parts involved can be treated more advantageously, in almost every instance, by other methods. As an assistant in the development of these surgical means, however, as a chemical disintegrator, as a source of heat, electricity has already rendered valuable service; while as a light-furnishing agent it bids fair to ultimately surpass all others. Had the term "electro-therapeutics" been strictly adhered to by the writer in the elaboration of this section, he would have found it necessary to omit the seven-tenths of what appears below, and deprive the readers of the work of what, to them, would have been of greatest interest. He has, therefore, concluded to take the broadest sense of the term, and incorporate the subjects likely to cover the wants of the specialist and, therefore, of the general practitioner.

Illumination.

Were electricity as generally used as other illuminants, many of the drawbacks militating against its universal use in laryngology would be obviated. As furnished in many localities, however, it occasions so much annoyance that the operator soon finds a return to the older methods, especially the petroleum-lamp, a marked relief. Connection with a general system renders him a slave of the repair squad, which naturally makes use of the day-time to make all necessary alterations and establish new connections; the current being usually turned off in the midst of the office hours. If collateral connections exist, their utilization generally involves a decrease in the intensity of light furnished,—a feature invariably presenting itself when a serious operation is about to be performed. The night-time being the usual working period of a general lighting system, those who require its assistance during the day, owing to their interference with the routine, are subjected to many petty annoyances, which are far from counter-balanced by the increased

advantages obtained, although these are many. Indeed, comparative absence of heat, whiter light, and absence of flickering are of no little import to the surgeon who is obliged to employ artificial light several successive hours each day. Storage-batteries depending upon outside recharging are usually unsatisfactory, for the amount utilized to produce sufficient light, added to the leakage, causes rapid exhaustion of the current, and the light gradually diminishes in brightness after the first few days. The process of recharging is a frequently-recurring source of annoyance, to say nothing of the dangers incurred by the instrument, when connected with a powerful dynamo-electric machine, in the process of recharging. True, gravity-cells in sufficient number might be employed as generators of currents instead; but the room required for a number of cells capable of keeping a second battery sufficiently charged for satisfactory incandescent lighting, the care required and the trouble involved, to say nothing of the frequent visits of a practical electrician to remedy frequent derangements in the accumulators, are discouraging elements to be borne in mind. Bichromate-of-potash cells as a battery are still less satisfactory. The light, as in the case of detached accumulators, remains good the first and, perhaps, the second day, and gradually declines as the solution becomes modified. Coupled with the precipitation of salts and the occasional breaking of a cell, thus causing a sulphuric-acid mixture to pour over and destroy any fabric, such as a carpet, etc., in proximity to it, a more irritating every-day companion can hardly be imagined

When, however, circumstances are favorable and a contract with a lighting company protects the physician against the annoyances mentioned, nothing is more satisfactory than a connection with a general circuit, provided, however, that it be not with an arc-light system, which invariably presents great danger. The current from an incandescent electric-light system is well adapted for laryngology, and is much better than any cell arrangement that may be contrived. Any number of milliampères is at the operator's disposal, in case of need, for motor, cautery, or electrolytic purposes, while the voltage required presents no dangers whatever to physician or patient. Of the utmost importance, however, is to interpose a current-controller in the circuit to properly regulate the amount of current allowed to flow through the instruments; otherwise more lamps, platinum loops, etc., will be destroyed in a year than would pay for four current-controllers. There are many on the market, but I can confidently recommend the Massey current-controller, which has served me faithfully. It is not only of value in electric lighting, but also in all forms of galvanic work in which shock is to be avoided,—a matter of special importance where any part of the head is to be treated.

Its range of resistance adapts it to all percutaneous currents up to as many milliampères as the battery in use can furnish. As

described by its author,[1] it consists of a ground-glass plate provided with tapering area of soft pencil-mark, bordering into thick graphite imbedded in the glass, which is joined to the lead. These act as resisting materials, over which a brass contact attached to a crank can be made to pass. When the crank is placed to the right of the hard-rubber button the contact rests entirely on the glass and the circuit is broken. Moving it slightly farther to the right, it soon touches the graphite-mark and permits the least amount of current to pass through, since the current must pass through the whole length of the graphite, —a poorly-conducting medium. As the crank is slowly brought down from the point of rest and up the other side there is a progressive gradual increase of current until, finally, the thick graphite and the lead at the left of the rubber button are reached, when the whole power of the battery is turned on. Continued use of this instrument causes the graphite to rub off in spots, but this may easily be corrected by means of the BBB Faber pencil.

Cabinets including all the attributes of laryngological practice and containing all required regulatory and controlling instruments offer many advantages for a specialist's office. Probably the most complete arrangement of this kind in existence is that recently described by Roaldes, of New Orleans,[2] and which this surgeon has had constructed for the Eye, Ear, Nose, and Throat Hospital of that city. It is reliable in its action, precise in its application, convenient in the varied uses to which it may be adapted, and quite economical, as far as the use of power is concerned. Unfortunately, the limited space allowed this section does not permit of an extended description of its different parts, but full details may be obtained by addressing the inventor.

Electroscopes.—For those who generally make use of the head-band, an instrument embodying the principle of the Trouvé-Hélot photophore, introduced some ten years ago, may serve satisfactorily. In this instrument a small incandescent lamp is attached to the band over the centre of the operator's forehead by means of a ball-and-socket joint. For gross work this position of the luminant will usually do; but when an operation requiring any degree of accuracy of vision and delicacy of touch is to be performed, the beam of light is not sufficiently close to and *en rapport* with the line of vision to give satisfaction. The result of an effort to remedy this defect is shown in the cut (Fig. 1), representing a lamp recommended by Robertson, of Newcastle-on-Tyne.[3]

The lamp is held over the bridge between the eyes, an improvement over the original photophore, but only perfect in action for those in whom the visual powers of both eyes are equal, because the subject to be examined, while forming the apex of a triangle of which the pupils

[1] Electricity in the Diseases of Women, by G. Betton Massey, Philadelphia, 1889.
[2] Transactions Pan-American Congress, 1893.
[3] Journal of Laryngology, February, 1892. (Manufactured by W. A. Hirschmann, Berlin.)

form the base, also becomes the focus of the beams of light. The majority of people are not favored with perfectly equal vision in both eyes unassisted by glasses, and to most operators the presence of a comparatively large projection between the eyes is a disturbing element of great magnitude, especially those in whom the interocular space is narrow.

To preserve as much as possible the advantages of the interocular disposition, I have modified the instrument in the following manner: The plate touching the face was so shaped to the brow as to accurately fit between the eyebrows immediately above the bridge of the nose. The eyes are not interfered with, and no impediment is presented to the wearing of glasses if these are needed. The lamp being connected with the head-band by means of a ball-and-socket joint, as in the original instrument, the beam of light may be projected as desired, *i.e.*, in accurate accord with the line of vision. The hinged head-band passing over the head to the occiput invented by Fox, of Philadelphia, in 1884, was substituted for the circular band generally employed, owing to the unpleasant heat around the head experienced while using the latter. The head-band is also utilized to support the conductors, which are thus held entirely out of the way.

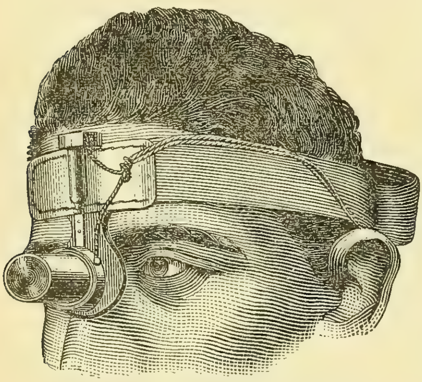

Fig. 1.—Improved Photophore.

For office work and under favorable conditions as regard current-supply, an arrangement such as that shown in the annexed illustration (Fig. 2) is, in my opinion, much to be preferred, mainly owing to the fact that perfect freedom of any connection with the instrument is enjoyed, while the beam of light is not turned away from the surface examined with each motion of the operator's head. It is mounted in the same manner as the student-lamp apparatus, the Tobold illuminator being connected with a post held in the piece employed in the oil-lamp for the purpose of holding the shade-frame. Free motion is thus preserved for every part connected with the production of light.

The carbon film shown in the cut (an Edison lamp) does not furnish perfectly-even illumination of the surfaces, owing to its horseshoe shape. The Swan or Maxim lamps are better in this particular, but not completely satisfactory. The former, by forming a loop, reduces the central shadows; the latter accomplishes the same effect by the U extension of the upright filaments, thus forming in reality four perpendicular white-hot rods, which greatly resemble, in joint effect, that of the Argand-burner oil-flame, with added brilliancy and steadiness. A good lamp having a

resistance of 60 ohms cold will necessitate a current of about from 1 to 1.3 ampères, representing an electro-motive force of about 50 volts, and, if not overheated, will last from 1000 to 1200 hours. On trying a new lamp the current-controller handle should be turned on with great care, lest the film be at once burned through. If a dip battery be used the elements should only be immersed very gradually, unless a current-controller be employed. If a storage battery be interposed between the general system patronized and the lamp, the rheostat or gradual resistance coil, which accompanies all carefully-made instruments, will enable

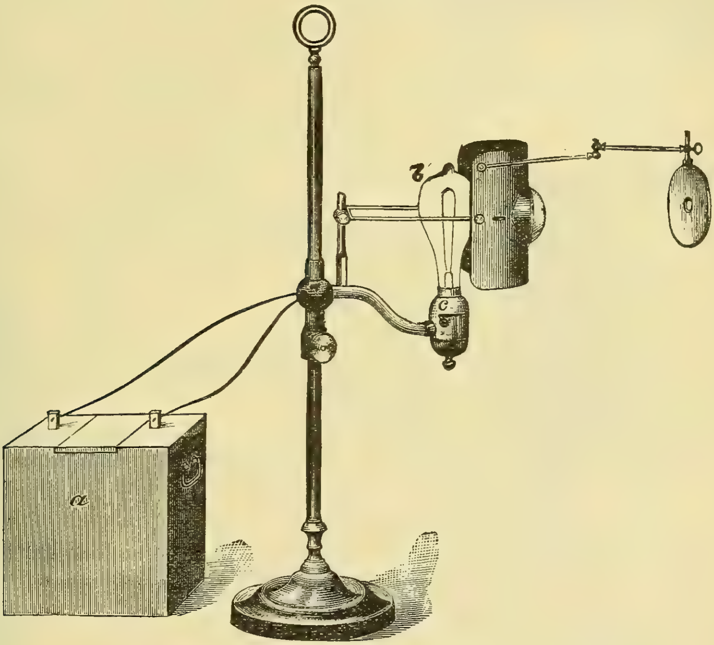

FIG. 2.—AUTHOR'S LAMP FOR ELECTRIC ILLUMINATION.
a, storage battery; *b*, incandescent lamp; *c*, circuit-closer.

the surgeon to avoid all danger without the use of the current-controller, which is but a modified form of rheostat.

Although I have had no opportunity to try it, the lamp shown on next page (Fig. 3), and recently introduced by C. W. Isaac, of London,[1] seems to present many advantages by doing away with all shadows. It consists of a small incandescent lamp so adjusted that the arch of the filament is as nearly as possible coincident with the focal point of a small, silvered, parabolic reflector one inch in diameter at its mouth. The reflector is pierced to admit the lamp, and mounted upon the extremity of a metal tube; in the tube slides a cylindrical block of ebonite, which serves as a carrier for the lamp; it can be fixed in any position by a

[1] British Medical Journal, December 31, 1892. (Made by Beddoe, 29 Nine Elms St., London.)

screw with a milled head which passes through the outer metal tube. The ebonite block contains two small brass tubes, which convey the current from the terminals at one end of the block to the lamp at the other. By a simple arrangement, not shown in the cut, a "burst" lamp can be replaced in less than a minute. The mouth of the reflector is closed by a small glass cover, which protects the lamp and prevents the silver from being quickly tarnished. Such an arrangement would, it seems to me, be quite advantageous for laryngological purposes, only the lamps as made (6 volts, taking 0.5 ampère) would be entirely too feeble for operative procedures. It could easily be fastened to the stand shown on page 5, and thus do away with the entire Tobold lens-cylinder and shield, excepting the conductor, which could be attached to the lamp-holder. An interesting and valuable instrument, based upon the principle that a glass rod will transport rays of light to its extremity without radiation of heat, was exhibited by Bélin[1] before the Academy of Medicine in Paris in March, 1889. The cœloscope, as he termed it, consisted of a small electric lamp hidden in a pear-shaped receptacle, to which glass rods of different dimensions could be fastened. Gaertner, of Vienna,[2] also constructed a lamp upon this principle, which is shown in the adjoining cut. A reflector attached to this instrument would doubtless turn it into an advantageous laryngoscopical apparatus.

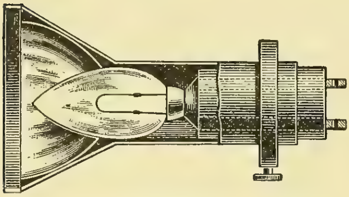

FIG. 3.—ISAAC'S SEARCH LIGHT.

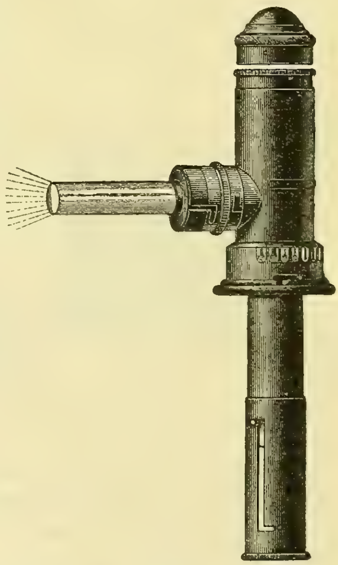

FIG. 4.—GAERTNER'S ELECTRIC LAMP.

I will mention the instruments calculated to combine mirror and electric lamp at the end of a shaft with a view of their introduction into the mouth, only to condemn them. A clumsy, bulky arrangement is thus obtained, which entirely defeats its object and usually succeeds in burning the patient's pharynx when the light is made sufficiently intense to satisfactorily illuminate the parts.

TRANSILLUMINATION.

Cozzolino, of Naples,[3] introduced a method which he called "posterior pharyngo-rhino-tuboscopy," consisting in the introduction of a

[1] Occidental Med. Times, June, 1889. [2] Wiener klin. Wochenschrift, April 4, 1889.
[3] Transactions of the International Congress of Otology, September, 1888.

small electric lamp mounted at the end of an ordinary galvano-cautery knife-shaft, behind and above the soft palate. This enables the operator, by looking into the nostrils, using a Duplay speculum with elongated and fenestrated branches, to examine all the parts usually seen with difficulty by means of anterior rhinoscopy. When septal deviation or other malformation or neoplasms do not interfere, the naso-pharynx and the posterior two-thirds of the anterior cavities can be examined directly; while transparent media may also be brought under scrutiny, if they project beyond the line of normal parts. The degree of light required need not be that necessitated for reflected light, as in instruments in which lamp and mirror are mounted together at the extremity of the handle; a much smaller lamp can therefore be employed and undue heat avoided. The parts to be examined should first be freely cocainized.

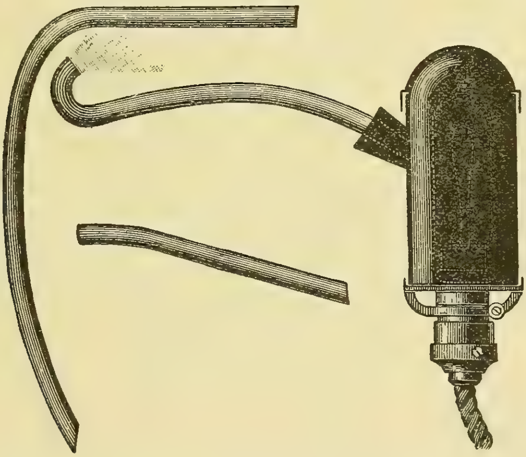

FIG. 5.—JACKSON'S TRANSILLUMINATING APPARATUS.[1]

Voltolini, of Breslau,[2] also introduced a method based upon the same principles, but including the nasal walls, the accessory cavities, and the larynx in the sphere of visual inquiry. For the examination of the larynx the lamp is applied to the external surface of the neck, at the pomum Adami or near the cricoid cartilage, and the heated laryngoscopic mirror is introduced into the dark pharynx. Freudenthal, of New York,[3] at a meeting of the Laryngological Section of the New York Academy of Medicine, thus described the results observed: "The light is quite different from that ordinarily obtained. The first thing that strikes the observer is the absence of different colors. The whole larynx shows a reddish tint of varying intensity. When we place the lamp at the level of the incisura thyroidea, the vocal bands and all the parts

[1] Tiemann, of New York.
[2] Monatshefte für Ohrenheilkunde, November, 1888.
[3] New York Medical Record, May 17, 1890.

above them appear of a beautiful red color (of course, the epiglottis is dark). But when we place the lamp near the cricoid cartilage we get a better survey of the whole subglottic region down to the bifurcation of the trachea, and this view is often more satisfactory than that obtained by the common method, etc." The circumference of tumors may thus be observed, a solid tumor may be diagnosticated from a cystic one, etc. As summarized by McBride, of Edinburgh,[1] transillumination of the upper air-tract includes the following features: "1. Allowing a strong light to fall on the exterior of the nose and then introducing a speculum from which all light must as far as possible be excluded. 2. Throwing a strong light into one nostril while looking into the other. 3. Introducing a mirror as in posterior rhinoscopy and throwing upon it a strong light while the anterior nares are inspected. 4. Introducing an electric light into the mouth and inspecting the nose. 5. Introducing a specially-constructed electric light into the naso-pharynx. On looking into the mouth the velum is seen to be illuminated, while the introduction of a nasal speculum will enable the observer to examine the anterior nares, especially in their posterior parts. 6. Introducing an electric lamp into the mouth and observing the transparency of the antrum of Highmore and the cheek."

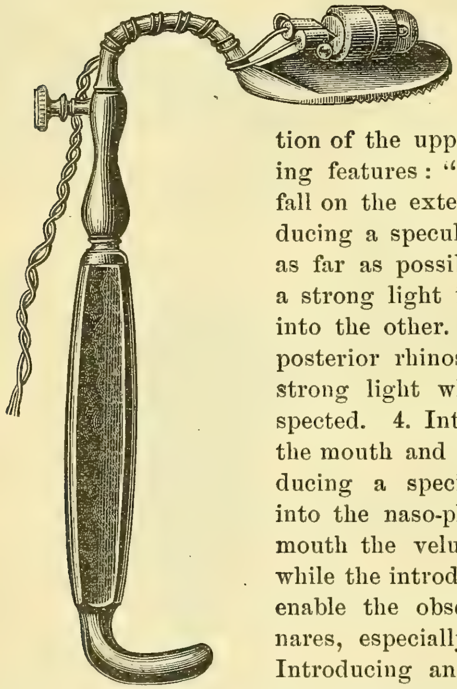

FIG. 6.—HERYNG'S MODIFICATION OF VOLTOLINI'S APPARATUS FOR THE TRANSILLUMINATION OF THE ANTRUM.

Chevalier Jackson, of Pittsburgh,[2] considers these procedures as not very practical, mainly because of the use of lamps of low voltage, which get hot, often burn out, are expensive to replace, and at best furnish but little light. He describes an instrument which, he states, obviates some of the practical disadvantages that have prevented the more general use of transillumination. The apparatus, which is illustrated on preceding page, brings into use the principle of Bélin's instrument for the transportation of rays of light through glass rods (see page 6). It consists of two parts,—an electric lamp and a silvered glass rod. The lamp is of 50-candle power, inclosed in a case silvered within and blackened without. Projecting from the side of the case is a metal neck into which fits a perforated asbestos cork; through the cork passes the glass rod.

[1] Diseases of the Throat, Nose, and Ear. London, 1892.
[2] New York Medical Record, October 29, 1892.

The latter, which may be bent into any convenient shape, is silvered over except at the ends, and the silvering is protected by varnish. The brilliant light within the lamp-case is transmitted axially through this rod and issues from the distal end with undiminished intensity. The rod does not get hot, and should be slightly warmed before introduction. A rod, hooked at the distal end, can be passed behind the soft palate; if the patient then close his lips, inspection through the anterior nares shows the nasal cavities brilliantly illuminated. Placed on the tongue, trans-illumination of the antrum is had, while the nasal cavities can also be enlightened,—the outer wall under the overhanging inferior turbinated more thoroughly than can be done in any other way. The distal end in one nostril illuminates the other nasal chamber. Placed externally over the thyroid cartilage, the larynx may be seen with the laryngoscope introduced warm in the usual manner, but without trans-oral illumination.

Electric Transillumination of the Accessory Cavities.—Voltolini's method of illuminating the antrum with an incandescent lamp has been extolled by many authors, first among whom was Heryng, of Warsaw, who devised the arrangement shown in the annexed wood-cut, consisting of an Edison lamp of 4 to 5 volts, attached to a tongue-depresser. In order to secure a satisfactory examination, the room should be darkened. The lamp being introduced into the mouth, and the latter closed, the degree of transparency of the superior maxillary region elicits valuable semeiological information. According to Heryng, the normal translucence is not produced in cases of empyema; the translucence of a serous cyst can, therefore, serve as a discriminating point from the latter affection, while distension may plainly be demonstrated. A point of importance is the presence of a large light spot under the lower lid, definitely developed when the antrum is clear, and decreased in extent or modified, according to the lesions present.

According to the opponents of the method,—Lichtwitz, of Bordeaux; Ziem, of Dantzig; Hartmann, of Berlin, and others,—it presents but little diagnostic value, because the luminous rays projected into the sinus originate not only from their direct source,—the mouth,—but also, indirectly, through the nose. The cavity is thus illuminated from two directions, the superior or nasal rays causing it to appear translucent whether pus (in small quantity) be present or not. None of these writers, however, totally deny that the procedure is possessed of merit; they admit that in many cases it is possible, especially where the quantity of pus present is great, to establish a diagnosis of empyema; but they also assert that it does not at all assist the practitioner in establishing a negative diagnosis,—an opinion with which most specialists concur. The frontal sinus may also be examined by the introduction of a small lamp into the nose, or by placing a lamp under the supra-orbital ridge.

Galvano-cautery.

Of all the remedial measures, galvano-cautery is, perhaps, the most frequently resorted to by the laryngological and rhinological specialist. In the nose, for the reduction of hypertrophic tissue, the cauterization of the seat of implantation of mucous polypi; in the pharynx, for the destruction of follicular nodules, the ignipuncture of tonsils; in the larynx, for the reduction of some forms of neoplasms, etc., its value is inestimable. It does its work neatly, to a degree aseptically, and, when *properly* utilized, painlessly and bloodlessly. In the nose and the larynx, however, it may occasion considerable trouble if injudiciously

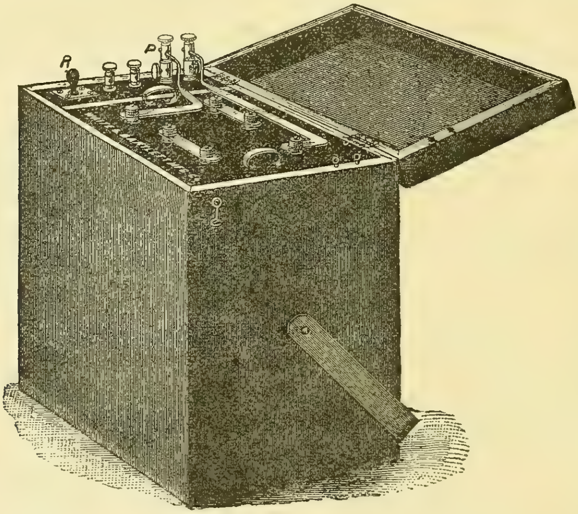

Fig. 7.—Waite and Bartlett's Storage Battery.

employed, the formation of cicatricial adhesions between proximate surfaces representing a result not infrequently obtained.

Unless the galvano-cautery *écraseur* or snare is to form a part of the operator's armamentarium and the lighting system used be in any way connected with his source of electrical supply, a small storage battery, such as the instrument shown in the cut, suffices. By keeping it connected with a set of primary cells varying in number with the kind available, gravity or open-circuit, it is kept charged, and, if needed for out-of-door work, may be disconnected and carried away, its power continuing unchanged for some time.

The obsolete dip or bichromate-of-potash batteries presented many unpleasant features which are done away with by the storage battery. The danger of allowing the elements to accidentally remain in the fluid, the motion of the foot or hand to bring elements and fluid together, are alone features sufficiently disagreeable to render such instruments most

objectionable. The only motion required to close the circuit being the digital pressure upon the handle-button, the foot-motion required with the dip battery is done away with,—a feature of no small importance when operations requiring precision are to be performed.

The choice of a proper cautery handle is also important. The majority of those sold, unfortunately, have their conductors connected with posts projecting from the rear end, making it practically impossible to operate with any degree of delicacy. To obviate this clumsiness I

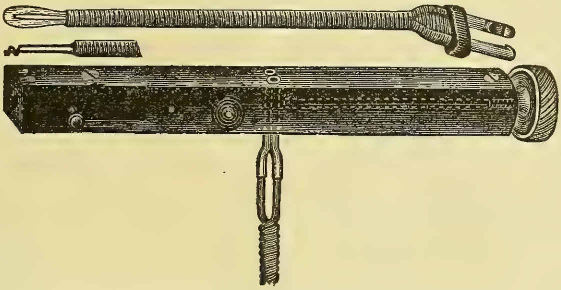

FIG. 8.—AUTHOR'S GALVANO-CAUTERY HANDLE.

found it necessary to have a special instrument constructed (that shown in the cut), which has stood the test of about ten years. Having been carefully gauged according to the laws of mechanics, even with heavy conductors the greatest precision is insured to every movement that the operator may wish to make.

As may be seen, the cords hang from the centre of the handle, thus insuring perfect equipoise between the resting-points when held, while the thread-screw serving to hold the cord-posts in place is calculated to compensate for the weight of the electrode at the other end.

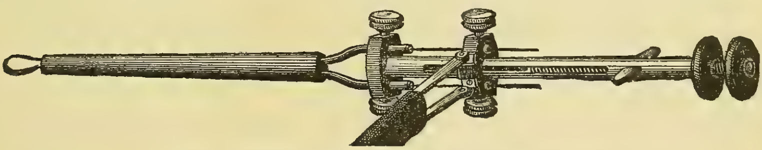

FIG. 9.—ALLEN'S GALVANO-CAUTERY SNARE.

Four electrodes are supplied with the instrument, shaped so as to conform with the outline of the parts to be treated.

When the galvano-caustic snare is to become a part of the surgeon's armamentarium, a more powerful current is necessary to overcome increased resistance. A most satisfactory galvano-caustic snare is that invented by Harrison Allen, of Philadelphia, and shown herewith. The body of the instrument consists of a slotted aluminium barrel containing a screw of equal length. The latter is connected with a vulcanite carriage, which moves freely over the barrel and serves for the attachment

of the wires and conductors. A milled nut at the end of the screw causes the latter to descend when turned, the loop being thus drawn home. In an instrument recently invented by Loeb,[1] of St. Louis, the shaft is insulated by means of hard rubber and can thus easily be kept clean.

Anterior Nasal Cavities.—In *acute rhinitis* galvano-cautery becomes of use not as a curative agent, but as a preventive one. In some individuals a few attacks of this disorder occasion a relaxation of the mucous membrane, owing to the inordinate tumefaction induced. This causes it to become hyperæsthetic not only under the effect of local influences, but also peripheral ones. What in most people would cause but a sneezing spell develops, in these individuals, an out-and-out attack of acute coryza, and as time advances these attacks become more frequent. After a time they form a source of no little suffering and the immediate etiological factor of chronic local affections.

This condition may be completely curtailed by means of a few applications of the flat side of a cautery knife at cherry heat over the most redundant portion of the membrane lining the inferior turbinated bones in each cavity. The cauterizations should be made after anæsthetization of the membrane with a 4-per-cent. solution of cocaine, one nostril only being treated at each sitting. By alternating sides and making an application twice a week, each cavity is given one week to sufficiently recover from the effects of the cauterization to permit a renewal of it. It is needless to say that the nose should be carefully cleansed with an alkaline solution before each operation. After the latter, a saturated solution of camphor in almond-oil should be applied with a pledget of cotton. Cleanliness of the nasal cavities should be insured by the bi-daily use of a one-drachm-to-the-ounce solution of bicarbonate of soda, used with an atomizer and followed by the application of camphorated oil to the cauterized side after each intra-nasal ablution.

In *chronic* and *hypertrophic rhinitis*, galvano-cautery possesses many advantages over any other method. Its application gives rise to but little pain, and the local inflammation following its use is so limited that it is hardly perceived in the majority of cases.

Chronic and hypertrophic rhinitis are so intimately allied in their career that a differentiation between them is difficult. As the hypertrophic process advances, however, the two affections gradually assume distinct types, not only in pathology, but in their subjective and objective symptoms. The differential diagnosis, therefore, resolves itself into determining whether the pathological condition present is as yet in that state in which it cannot be distinguished from the simple chronic condition, in which case simple applications of the cautery knife would be indicated, or whether the pathological changes are of a nature requiring the use of more-active measures for the absolute removal of the redundant tissue formed. The mere application of the cautery knife would here

[1] Journal of the American Medical Association, October 22, 1892.

produce but little effect; the cold or cautery snares are alone able to meet the needs of the case if positive benefit is to be obtained. The resiliency of the membrane, when pressed upon, furnishes means by which the presence of hypertrophic tissue can be estimated; we have, in cocaine, an adjunct enabling us to correctly determine the proportions of the tissue, and therefore a guide in the selection of a proper remedial course to be adopted. As I already had occasion to show,[1] after the application of a 4-per-cent. solution, the contracted membrane, emptied of its fluids as much as its organized tissues will allow, assumes a superficial shape corresponding topographically with these underlying organized tissues, and the presence of areas of neoplastic formations may correctly be estimated. In uncomplicated chronic rhinitis the contraction is about complete, the pathological changes consisting mainly in infiltration. The membrane appears smooth and uniform, the conformation of the bones beneath being often discernible. As soon as sufficient neoplastic tissue has formed to become discernible, however, the smoothness and uniformity are lost and irregular prominences appear, especially at the posterior ends of the middle and superior turbinated bones. In marked hypertrophic rhinitis —a rare condition in the anterior portion of the nose, a common one in the posterior—lobular prominences may be observed, often presenting the conformation of broad-based neoplasms. It stands to reason that the mere and even repeated applications of a cautery knife, in the latter class of cases, would hardly suffice to occasion anything beyond temporary relief.

Uncomplicated chronic rhinitis may be advantageously treated in the manner indicated under the preceding heading. In the early forms of hypertrophic rhinitis, when organized tissue is still limited, a linear incision into each of the areas of redundant tissue, in addition to applications such as indicated in the simpler forms of rhinitis, will generally suffice to obtain a cure. In order to obtain the best effects, however, the platinum loop should be applied glowing. After thorough cleansing, the nostril is properly illuminated and the parts are anæsthetized. A speculum is then introduced and the knife is passed into the nostril cold, and placed over the spot to be cauterized. The circuit is then closed by touching the handle-button and the glowing loop is pressed into the tissues and left there about one second. The circuit is then broken and the instrument withdrawn. As a result, the different layers of the membrane are severed; some of the blood-vessels and sinuses are obliterated and cicatricial bands are formed, which hold down the membrane within proper bounds. The after-treatment should consist in keeping the nostrils clean, and in the local application of camphorated oil as previously indicated. Renewal of the applications should correspond with the number of lobular prominences, twice a week being a safe limit under all circumstances.

[1] Lectures on Diseases of the Throat and Nose. Philadelphia, 1885.

An important point in connection with the operation is the proper regulation of heat. When the platinum blade is not sufficiently heated —black heat—it causes severe pain. When it is too hot—white heat— it may cause severe hæmorrhage by incising, as would a cold knife. *Cherry* heat is hardly felt even without anæsthetic, causes no bleeding, and is more efficient as far as results are concerned than either of the other two.

After all galvano-cautery applications the nostrils should be carefully examined at each visit until complete healing of the parts, lest the local inflammation cause adhesion between the spot cauterized and the septum. Cicatricial bands greatly limiting the lumen of the cavity treated may follow neglect of this precautionary measure.

When the hypertrophic projections of the membrane are very large, as is frequently the case in the posterior portions of the anterior cavities, this treatment is not sufficiently effective. The projecting tissue must be relieved. This can be done with the cold-wire snare; but if, in order to reduce the chances of hæmorrhage, the operator wishes to use the galvano-cautery loop, the growths must first be transfixed with a needle to enable the loop to grasp the tissues. For this purpose Jarvis's transfixing needles may be employed. One of these being passed through the growth, the cautery loop is passed into the nasal cavity, over the handle of the needle and over its point as it protrudes from the surface. The wire being then tightened around the growth, the circuit is closed and the wire allowed to burn its way into the tissues a short distance. This being repeated a number of times, the mass is gradually penetrated and detached near its base. The parts usually heal without trouble, the after-treatment varying in no way from that already indicated.

Another effective and perhaps less-complicated means of removing these growths is with the assistance of the instrument invented by Vulpius, of New York,[1] calculated to pare off the redundant tissue on the principle of the soap-cutter. The main parts of the instrument will be easily understood by examining the annexed cut. The platinum loop is stiffened by the addition of iridium,—a great advantage. The instrument is introduced into the nostril through a spacious speculum, after having shaped its loop and shank end so as to make them exactly suit the individual case. The loop attacks the projecting tissue from behind, the shanks bordering it above and below. By gentle pressure under closed circuit, alternated as explained above, it is soon completely removed.

The galvano-cautery, as shown by Cartaz, may also be advantageously used to destroy small tuberculous ulcerations of the nasal cavities. This may be done painlessly by the previous application of a 20-per-cent. solution of cocaine.

The galvanic loop may be utilized in the same manner for the

[1] New York Medical Journal, April 22, 1893.

removal of neoplasms, such as fibromata, large hæmatomata, etc., in which severe hæmorrhage is to be feared. In all others, including mucous polypi, other measures are much to be preferred. In all forms of growth, cauterization of the seat of implantation subsequent to instrumental removal, after anæsthetizing the parts with a 10-per-cent. solution of cocaine, is the most effective measure to prevent recurrence. Electrolysis, it will be seen, accomplishes removal and prevents recurrence without requiring subsequent cauterization.

For the treatment of *hay fever* it is very essential to have a battery powerful enough to cause the platinum loop to suddenly attain white heat, so as to avoid the pain caused by the gradual increase of the temperature and prevent prolonged radiation. The loop should also be sufficiently blunt at the point and edges not to cut or scratch the membrane when gently passed over it. The nasal cavity being properly dilated and illuminated, the cautery knife is introduced gently and applied flatwise. If the part is not sensitive the patient will not wince, the sensation being hardly more than a slight itching. If it be hyperæsthetic, a feeling of intense itching or burning will be complained of, followed in some cases by profuse lachrymation. As soon as the evidences of abnormal sensitiveness appear care should be taken not to move the platinum tip, and, the circuit being closed, the metal singes the spot, destroying the superficial nervous filaments. If the platinum become white-hot immediately, comparatively little, if any, pain will be experienced, but the contrary will certainly be the case if a weak current or a knife so thin that the nasal mucus will prevent it from becoming heated rapidly is used.

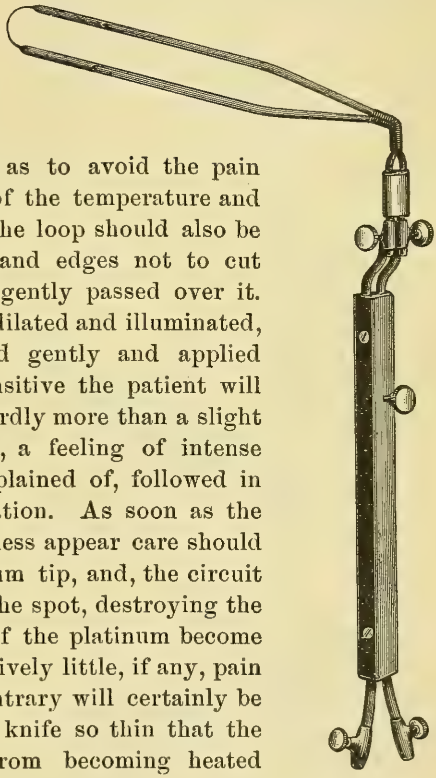

Fig. 10.—Vulpius's Electric Nasal Curette.

One spot being cauterized, another sensitive spot is searched for by gently passing the loop over the surface until the patient complains of the sensations experienced before, when the current is again applied. In this manner the entire respiratory area should be gone over until the instrument can be applied to any part of the membrane without exciting reflex symptoms or causing the violent itching or burning, which the patient soon learns to recognize.

The pain accompanying these applications varies according to the degree of heat employed. White heat, which cauterizes in an instant, destroys the nerve-filaments before they have time to convey the sensation of pain to the nerve-centres. Cherry heat causes some pain, while

black heat is exceedingly painful. White heat, therefore, should always be employed for superficial applications.

The cauterizations should always be begun in the anterior portions of the nasal cavity, so that the anterior hyperæsthesia will not be present when the posterior parts are examined, and thus conceal the sensitiveness or convey a wrong idea as to its location. The septum should be as carefully examined as the turbinated bones, and any spot of even doubtful hyperæsthesia cauterized.

Three or four spots in each cavity can be cauterized at one sitting, and it is best to locate them some distance apart. A sensitive spot being found in the upper part of the anterior area, for instance, and cauterized, the next spot should be looked for in the lower part of the septum, etc. In short, the object should be to avoid large superficial abrasions, numerous small ones healing much faster and producing no disagreeable after-effects. In the great majority of cases, a few minutes after the applications are made all annoying sensations are passed, and the patient can return to his business without fear of being in the least troubled. In some few, however, the membrane swells for awhile and the patient may experience difficulty in breathing through the nose. When such is the case, one nostril should be treated at each visit, so as to preserve for the patient the patency of the other, and thus insure him comparatively free respiration.

Diseases of the Naso-Pharynx.—Although galvano-cauterization has been recommended by several prominent authors in the treatment of posterior nasal inflammatory disorders, it is but little used,—a fact probably due to the difficulty of the manipulation, which requires considerable experience on the part of the operator and a certain amount of training on the part of the patient if his pharyngeal cavity is rebellious. The local application of cocaine, however, greatly facilitates any measure attempted in this region, if care be taken to include the back part of the soft palate, the pharyngeal wall, and the base of the tongue in the anæsthetization. In the so-called "post-nasal catarrh," careful ablution of the parts twice a day, by the inhalation from the hand of a one-drachm-to-the-pint lukewarm solution of bicarbonate of sodium, and bi-weekly application of galvano-cautery to the crypts and recesses of the parts giving rise to exudation, constitute one of the most effective measures in the treatment of this stubborn affection. Great care should be exercised, however, in the treatment of this as well as other disorders of the posterior nasal cavities, lest the Eustachian orifices become involved in the burning process. The thinness of the mucous membrane in this location, however, renders the formation of cicatricial bands a danger to be apprehended, thus materially compromising the patency of the orifice, and therefore the hearing of the side accidentally burned. Of all importance, therefore, is an instrument in which the cautery knife is carefully covered to prevent searing of the surrounding parts when the circuit is

closed. Such an instrument is shown in the adjoining cut. The loop as here represented may be used not only in the treatment of post-nasal catarrh, but also in the destruction of small adenoid vegetations, fibromata, or any other form of tumor peculiar to the parts, but which have not as yet attained marked development.

As may be seen in the illustration, a suitably-bent electrode with a small loop presenting a surface about as large as a pea, and covered as stated with a hood to prevent burning of the surrounding parts, is passed behind the soft palate and located over the most prominent portion of

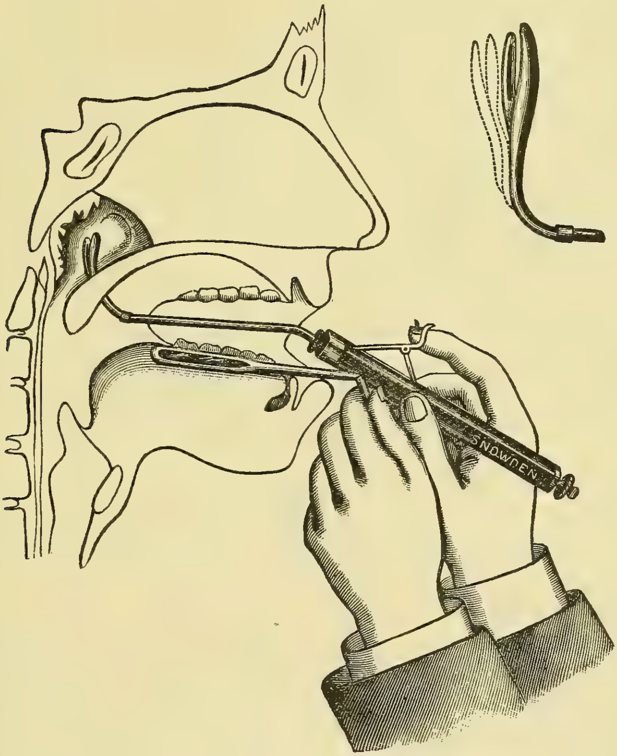

FIG. 11.—POST-NASAL CAUTERY KNIFE IN POSITION.

the growth, with the assistance of the rhinoscope,—after, of course, the application of a 10-per-cent. solution of cocaine to render the procedure painless. The current being then turned on, the glowing metal is left in contact with the mass a couple of seconds. The electrode is then moved slightly and another cauterization is applied, this procedure being repeated three or four times without removing the instrument. Slight bleeding sometimes follows the operation, which is painless and not followed by disagreeable after-effects if properly executed. An excellent instrument for this purpose was contributed by Beverly Robinson, of

New York,[1] the protection afforded the parts being obtained by means of a cup-shaped shield which adjusts itself to the tissues submitted to the cauterization.

The instrument shown in the illustration (Fig. 11) can also be utilized for the removal of large post-nasal growths by substituting the curved-snare tube for that containing the cautery knife. In suitable cases the straight-snare tube may be used by passing it through the anterior nares. The selection of the tube depends, of course, upon the position of the tumor and its shape. If sufficient time be taken for the operation, but little if any blood is lost; while cocaine, applied thoroughly to the parts, renders the operation painless.

When the polypus grows from the roof of the cavity, is not too large, and hangs downward, the operation is best performed through the nose, the loop being adjusted as near as possible to the seat of implantation by a finger passed behind the soft palate and held there until firm grasp is obtained. One hour at least should be employed to gradually penetrate the mass if hæmorrhage is to be prevented. When the tumor is very large and occupies and even distends the lumen of the isthmus, the finger cannot be introduced so as properly to adjust the loop around the base of the growth; the curved tube in this case may be advantageously employed. The posterior implantation being lower than the anterior, the loop should be slipped over the growth in the natural way; that is to say, with the tube in front. Its tip being pushed upward until the roof is touched, the loop is thus dragged over the growth to the seat of implantation.

Irido-platinum wire will be found to give better satisfaction than pure platinum in these cases. Casselberry, of Chicago,[2] prefers steel wire, owing to its resiliency; he found it to assume red heat as well as platinum wire, although it requires to be changed at each sitting,—an insignificant objection.

When the growth is sessile and cannot be grasped, a curved transfixing needle can be passed through it, its introduction being conducted with the assistance of the rhinoscope, or a furrow may first be burned into its base with the cautery loop, as shown by McBride, of Edinburgh,[3] thus enabling the operator to obtain a firm grasp. In pedunculated tumors Wagner, of Lille,[4] employs the following procedure: The tumor being partially seized with the galvanic loop with rather large wire, the loop is tightened and the current passed for an instant *without traction*, so as to obtain adherence between the metallic wire and the tumor. He continues to press the wire without cutting the tumor until a sudden traction movement detaches the polypus from its insertion.

Pharynx.—Galvano-cautery gives by far the best results in the form

[1] Transactions American Laryngological Association, 1884, p. 147.
[2] Journal of the American Medical Association, April 21, 1889,
[3] Edinburgh Medical Journal, August, 1889.
[4] Journal of Laryngology, October, 1889.

of pharyngitis generally called "clergyman's sore throat," *i.e.*, follicular pharyngitis. Besides being a painless means, it gives rise to no disagreeable after-symptoms and does its work effectually. A small platinum loop, twisted at the end so as to form a miniature corkscrew, is the most satisfactory electrode; it penetrates deeply into the inflamed follicle, and is followed by no secondary disturbance, especially if the tip be brought to a cherry-red heat Each engorged follicle should be touched after carefully dressing the pharyngeal wall with an alkaline spray. Not more than four or five follicles should be burned at one sitting (the majority of operators cauterize too many at a time, thus giving rise to a form of subacute pharyngitis more difficult to overcome than the follicular), several days being allowed to elapse before another series of cauterizations is attempted. Hardly any discomfort is caused during the operation, and slight soreness, lasting a couple of days, represents about all the after-effects. With the destruction of the follicles disappears the surrounding inflammation, and almost immediate relief ensues. When the superficial vessels are large and show evidence of varicosity, the larger ones should be cauterized, the tip being applied a couple of times in the course of the vessel showing through the membrane. The after-treatment should consist in abstinence from alcoholics and highly-seasoned or too-hot food.

Tonsils.—In the treatment of the disorders of the tonsils, galvano-cautery is an agent of much value. The destruction by ignipuncture or snaring of the neoplastic tissue forming hypertrophy, and the cauterization of the crypts in the follicular form of tonsillitis, may, perhaps, be more successfully performed with its assistance than with that of any other agent. It cannot be satisfactorily employed in young children, however, especially for the removal of hypertrophied tonsils, and other instruments, such as the guillotine, are preferable.

In the follicular form of *chronic tonsillitis*, in which the crypts or lacunæ are filled with a cheesy material that maintains in them a latent form of inflammation, which is the cause of fetid breath in many persons, and frequently gives rise to spasmodic cough, the galvano-cautery knife may be utilized with marked advantage to destroy the pyogenic-like membrane lining the crypts. These having been thoroughly emptied of their contents, the glowing knife is projected into each cavity and left there a second or two. Several crypts may thus be destroyed at each sitting without causing the least unpleasant after-effects. After each lacuna has thus been thoroughly obliterated the tonsils shrink to their normal dimensions.

Galvano-cautery may be employed in several ways in the removal of *hypertrophied tonsils*,—galvano-puncture, the loop, and the galvano-cautery amygdalotome,—all of which, however, are, as stated, difficult of application in children In the latter, therefore, unless unusual docility render it unnecessary, an anæsthetic had best be administered. The use

of the cautery reduces to a very great extent the chances of hæmorrhage,—its principal merit over other procedures, such as ablation with knife, the amygdalotome, etc.

Ignipuncture has had many advocates, prominent among whom may be mentioned Krishaber and de Saint-Germain, of Paris, and Knight, of New York. The tonsils and neighboring parts having been anæsthetized with a cocaine solution, the tip of an electro-cautery knife is inserted into the parencyma when glowing, the stab being repeated several times, but each time in a different spot. Five or six punctures in each tonsil may thus be administered at each sitting, a period of two or three days intervening between the latter. Fifteen to twenty sittings are usually necessary to obtain a satisfactory result in rather large growths. This may be hastened somewhat by crucial or gridiron incisions over the most prominent portions of the mass. After a certain number of operations the tonsils become ragged with projecting teats and prominences. A pair of curved scissors may sometimes be used advantageously to trim the edges, or the cautery knife may be used to pare the projecting tissues off their seat of implantation.

The galvano-cautery loop may be used in the manner indicated for post-nasal tumors, advantage being taken of the same measures if the base of the growth render the holding of the growth within the grasp of the irido-platinum loop impossible. Care should be taken to tighten the latter before closing the circuit, so as to, as it were, bury it into the tissues to be cauterized, and thus protect the surrounding surfaces,—a feature of no little importance in the technique of this operation. The loop should be called home slowly, so as to cauterize but little tissue at a time, the current being allowed to flow intermittently. The portion removed by the loop does not indicate the real extent of the operation, for a portion of the normal tissue sloughs, thus reducing the thickness of the stump remaining after the operation. The pain may almost be entirely prevented by the local application of a 10-per-cent. solution of cocaine, a thin probe covered with cotton-wool being used to introduce some of the solution into the crypts. The unpleasant odor of burning tissue is about the most disagreeable feature of this operation, but patients do not seem to mind it much. Sendziak, of Warsaw,[1] prefers a steel wire to a platinum, and avoids cauterization of the adjoining parts by grasping the tonsil with a hook and drawing it out of its bed while the snare is doing its work.

Tonsillotomy may be relieved of its awe-inspiring danger—hæmorrhage—by the use of Wright's galvano-cautery tonsillotome, an adaptation of the Morell Mackenzie amygdalotome to galvano-cautery purposes. Instead of the steel blade, a non-conducting material, compressed paper, is used and one end hollowed out into a crescent. Across this is stretched a platinum wire, which represents the sharp edge of the

[1] Revue de Laryngologie, February 15, 1893.

cutting instrument. This is connected by means of copper wires inlaid along the sides of the blades with the binding-screws of the other end. Here, by means of the ordinary spring, the circuit from a cautery battery is closed by the pressure of the thumb as the blade is driven against the mass included in the loop of the instrument when adjusted.

This instrument can be as easily adjusted as the ordinary tonsillotome. The tonsil can also be removed as rapidly as with the knife if the wire is heated white-hot, but in that case the prevention of the hæmorrhage could not any more be counted upon than if the operation had been performed with the knife. Cherry heat, therefore, is preferable, the mass being slowly cut through.

Pynchon, of Chicago,[1] advocates the removal of hypertrophied tonsils by electro-cautery dissection, a set of bent electrodes serving to gradually detach the growth from its seat of implantation, beginning with the attachment to the pillars. The blade is entered cold, and, the circuit being closed, the adhesions are gradually severed until complete separation, when the tonsil is grasped with forceps and removed. The operation, according to the author, is somewhat tedious, requiring from fifteen minutes to one hour.

Larynx.—The application of galvano-cautery in the treatment of laryngeal affections is limited, owing to the cicatricial contraction following its use, and which seems to be more marked in this than in any other portion of the upper respiratory tract. Of no little importance in this particular, also, is the difficulty of the manipulation—which, in fact, should only be undertaken by experienced hands—of the galvano-cautery instruments within the laryngeal cavity; the spasmodic contractions of the ventricular bands, the retching, etc., being as many interfering media as any operator would care to encounter when the heated electrode is in the larynx. For this reason only a very small tip should be used, so as to enable it to become immediately cooled in case the operator should find it suddenly necessary to open the circuit in order to prevent cauterization of the tissues spasmodically grasping the electrode. A 20-per-cent. solution of cocaine applied a few times in succession greatly reduces the sensibility of the larynx, and therefore proportionately limits the reflex effects produced by touching its mucous surfaces.

A point of importance in connection with laryngeal electrodes is that the majority, as sold in shops, are too short to enable the operator to reach the desired point. To satisfactorily conduct the manipulation a correct idea should be obtained of the depth of the parts to be touched —usually the vocal bands—by means of a pliable probe; an electrode of proper length can then be selected. Again, polished instruments when in position reflect the color of the surrounding surfaces and are, therefore, not easily to be seen. This may be obviated by exposing the

[1] Journal of the American Medical Association, November 22, 1890.

laryngeal end of the instrument to a flame, thus causing it to assume a bluish-black color, offering quite a contrast with the light-pink hue of laryngeal surfaces.

Galvano-cautery is mainly used in the larynx to remove tumors which are not removable by forceps, such as sessile fibromata, small nodular growths of the surface of the bands, tuberculous vegetations, and the base of neoplasms removed by forceps to prevent recurrence. Owing to its tendency to cause cicatricial contraction, its use should as much as possible be limited, when regions such as the interaryteniod space or the ary-epiglottic fold are treated, the free motion or pliability of which plays an important part in the performance of local functions.

The round tip, the knife, and the snare may be employed in this region, according to the shape and size of the tumor to be removed. The parts having been properly anæsthetized and the larynx well illuminated, the manipulation is to be conducted under the guidance of the laryngeal mirror. Before the introduction of cocaine the parts required prolonged preparation in order to enable them to tolerate the instrument in the larynx a certain length of time without the induction of reflex spasm. These preparations are, fortunately, no longer necessary.

Electrolysis.

The decomposition of water by an electrical current, oxygen going to the positive pole and hydrogen to the negative, as shown by Volta, represented an electro-chemical action which Humphry Davy applied to animal tissues, but which a French surgeon, Fabré-Palaprat, was first to utilize in the treatment of disease. The insertion into an animal tissue, such as a piece of meat, of two ordinary needles, one connected with the negative pole and the other with the positive pole of a battery, and the passage through them of a strong current for a few minutes will cause the following changes: softening and disintegration of the tissues surrounding the negative needle, and the presence around it of a cavity containing liquids and bubbles of hydrogen-gas. The latter are emitted during the process of electrolization, producing a crepitant noise and a frothy exudation as long as the circuit is closed. The negative needle, which can be extracted with ease, will be found to have retained its polish and remained bright. The hydrogen, as in the case of water, has therefore been attracted to the negative pole; the oxygen, as will be seen, will also follow its accustomed course. The positive needle, on the contrary, will be found, upon extraction, to have become greatly oxidized, —*i.e.*, rusted and corroded,—while the cavity in which it was imbedded will have become surrounded by an eschar varying in extent with the intensity of the current employed, and representing precisely the result reached by means of an escharotic. The chemical transfer action may further be demonstrated by means of litmus-paper, the fluids connected with the positive puncture turning it red, while no change can be ob-

tained when the paper is dipped into the fluids representing the negative pole. Of clinical importance is the fact that of the two areas thus chemically modified that treated to negative action will sooner yield to absorption, owing to the liquid state of its component elements, and therefore pass through the process of resolution with more rapidity. When a single needle is to be utilized, the negative pole should therefore be connected with it, the positive with the external or peripheral electrode. That the introduction of both needles into the area treated in the electrolysis of neoplastic growths of the upper respiratory tract is a preferable measure, however, is readily demonstrated practically as well as theoretically. In the unipolar method the flux lines of the solitary needle inserted into the tissues involve to a marked degree (though producing no chemical alteration beyond the immediate neighborhood of the needle) the parts they traverse on their way to the dispersing or positive electrode. In the bipolar method the proximity of the needles causes the current to involve to a greater or less degree, according to the intensity of the current, the small area of tissue about them, the flux lines therefore traversing nothing but tissues involved in the sphere of operation. Another point of importance secured is that the proximity of the electrodes causes a great reduction of tension, and therefore limits in proportion the influence of the nervous elements of the region. By this limitation of potentials much pain occasioned in the monopolar method by the superfluous dispersion of fluid is saved, the success of the operation is more certain, and the implication of parts other than those within the domain of the intended operation avoided. Thus, the neuralgic pains, flashes, etc., during and after the operation are practically avoided, and resolution is much more prompt.

Electrolysis has been mainly utilized for the destruction of neoplasms of the anterior and posterior nasal cavities, and the reduction of hypertrophied tonsils. In the larynx its use has been quite limited,—a fact easily understood when it is remembered that the needles should remain imbedded in the tissues several minutes at a time if satisfactory results are to be obtained The supporters of the method claim for it many advantages, most important of which is the bloodlessness of the operation. "Indeed," says D. S. Campbell, of Detroit,[1] "all things being considered, where a growth cannot be properly extirpated by either the crushing or cutting process without injuring important structures; or when a surgical procedure would be highly proper, but cannot be performed without doing violence to other parts, as, for instance, where the tumor is situated behind the posterior surfaces of the turbinated bodies, or in vascular growths occupying any portion of the nasal tract where any procedure except pressure is of account—not excepting actual cauterization—nothing can accomplish so handily or so safely the removal of these growths as the galvanic current."

[1] Journal of the American Medical Association, August 25, 1888.

The number of treatments necessary in a given case depends upon the density of the tissue present and the character of its component parts. Growths of slow formation are usually slower in their response than those of rapid growth, a fibrous tumor, for instance, requiring much more time and a greater number of sittings than an adenoma. Again, the size of the tumor naturally influences the number of sittings., although by the use of deeply-buried needles at the active pole if the monopolar method is used, and at each pole if the bipolar, supplemented by increase of the current-intensity, both of these counteracting elements can to a great degree be reduced in importance.

As already stated, a battery presenting a small degree of tension should be preferred, to reduce as much as possible the influence upon the nervous system of the monopolar method when employed. In the bipolar this precaution is not as important, the small area of tissue to be traversed reducing almost to naught the degree of tension. With the latter method very large growths can be treated with more certainty of success, as the intensity can be increased to thirty, forty, etc., without inconveniencing the patient.

Anterior Nasal Cavities.—Probably the most effective application of electrolysis in the anterior nasal cavities is the destruction of thickenings accompanying deviations of the septum, ecchondroses, etc. Without presenting many of the unpleasant features accompanying the use of the saw, the drill, the chisel, etc., it does its work quite as effectually, and, if properly applied, in some cases in one sitting. Miot, of Paris,[1] was first to introduce electrolysis in this class of cases. Since then it has received considerable support in papers by Garel, of Lyons;[2] Bergonié and Moure, of Bordeaux;[3] Flatau,[4] and others. Heryng, of Warsaw,[5] and a few other observers have reported adversely, the main reasons being the duration of the treatment and the likelihood of perforation of the septum, The latter complication, it may here be noted, is much more likely to occur when the monopolar method is used. The bipolar reduces the chances of perforation to those accompanying other operative procedures.

The instruments used by Miot are shown in the annexed cut. In order to reduce as much as possible oxidation of the needles they can either be made of gold or platinum, although the fact that steel needles are introduced much more easily, coupled with the ease with which they can be replaced, greatly invalidates their recommendation.

Miot, who uses the monopolar method, usually employs steel needles, the positive pole instead of being connected with the needles, which would

[1] Revue Mensuelle de Laryngologie, May and June, 1888.

[2] Annales des maladies de l'oreille, October, 1889.

[3] Du traitement par l'électrolyse des déviations et éperons de la cloison du nez, par J Bergonié et E. J. Moure, Bordeaux, 1892.

[4] Wiener medizinische Wochenschrift, No. 12, 1892.

[5] Przlegad Lekarski, Nos. 1, 2, 7, 8, 11, 12, and 13, 1892.

become oxidized, being connected with the surface electrode. The negative needle remains clear, whatever the metal of which it is composed or the strength of the current may be. The different shapes shown in the illustration facilitate their application in the different conformations of cavities and growths met with, while the sheath, which may be observed to reach up to within one-half inch of the point, being made of some non-conducting material, such as rubber tubing, serves to insulate the portion of the shaft not buried into the tissues. The exposed portion can easily be lengthened when thick growths are to be penetrated by paring off the superfluous portion of the insulating sheath.

Of importance in the technique of the procedure is the proper regulation of the quantity of current to be utilized during the treatment, a milliampèremeter being, therefore, a *sine qua non*. Bergonié, in his able work, written in connection with Moure, of Bordeaux, recommends an instrument of his own, resembling somewhat in construction the Bailey

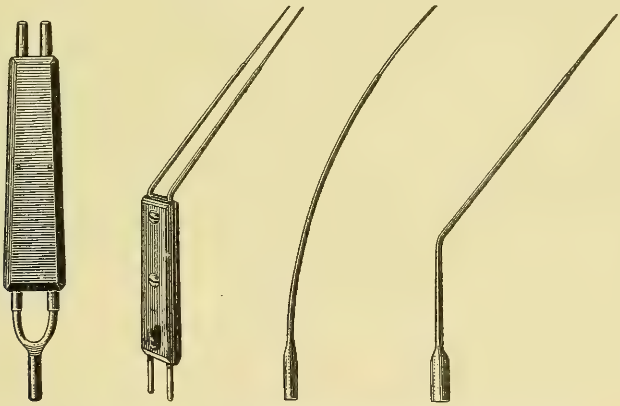

Fig. 12.—Miot's Electrolytic Needles and Handles.

current-controller. I have had no experience with this instrument, but have obtained valuable assistance from Massey's, described on page 3.

To measure the current the most satisfactory instrument I have used is the McIntosh milliampèremeter.

The use of this instrument, however, requires considerable care, as do all instruments of this class, and it should not be brought into a circuit without being preceded by a current-controller. A description will be found in the chapter on "Galvanic Current." For electrolytic purposes in small growths the short scale-marks from 0 to 20, the spaces from 0 to 5 indicating half-milliampères, will usually be sufficient.

The technique of the operation is simple enough. The nasal cavity treated having been properly illuminated and the parts thoroughly anæsthetized with a 10-per-cent. solution of cocaine, the needles are inserted about one-quarter of an inch apart, as much as possible longitudinally with the axis of the growth to be destroyed. The current-con-

troller having previously been adjusted to 15 milliampères, the circuit is then closed and the electrolytic action allowed to continue four minutes; the intensity is thus increased to 20 milliampères by slowly bringing the crank of the controller around until the indicator of the meter shows the desired number. Another four minutes should be employed with this intensity, when it should be reduced to the previous one (15), this being kept up until the end of the twelve minutes, the duration of the entire sitting. That 20 milliampères are ample was more than demonstrated by Grünwald,[1] who in a report of twenty-four cases had never used more than 15.

The reaction is generally very slight and cocaine renders the procedure painless. After ten days or two weeks the cartilaginous or bony sequestrum falls off and the surfaces rapidly assume the appearance of the surrounding parts. Occasionally the removal of the sequestrum needs a little assistance, especially if the needles have been introduced too far from the surface. Forceps usually suffice to detach it from its base. In large growths double or triple needles mounted on one or both electrodes, as shown in the first and second figures of the illustration on preceding page, may be advantageously utilized to increase the sphere of electrolytic action, or the sittings may be repeated, a small portion being destroyed at each visit. The after-treatment preferred by Bergonié and Moure, who introduced the bipolar method, consists in keeping the parts clean with solutions of boric acid, this agent being also dusted over the parts, and in trimming what irregularities of the membrane the loss of the sequestrum may have involved.

Electrolysis may be utilized in like manner in any form of tumor within reach, but zinc needles seem to have obtained better results than gold, gold-plated, or platinum ones. In a case reported by Shipman,[2] an enormous fibroma, well advanced in its destructive career, rapidly yielded to the zinc needle after unavailing efforts with a gold-plated one, although all other attachments were the same. The softness of this metal, however, renders its use impossible in cartilaginous or bony tissue unless a hole be previously made with a steel needle. The electrolytic method is especially valuable in tumors in which dangerous hæmorrhage is likely to follow the employment of other means.

In *hypertrophic rhinitis* it has been tried by a large number of operators, with varying results, all of whom, however, have used only the monopolar method. The softness of the tissues usually makes an intensity of over 10 milliampères unnecessary. The method has again come somewhat to the fore, of late, through the recommendations of Flatau,[3] Scheppegrell,[4] and Garrigou-Désarènes.[5] By carefully regulating the

[1] Deutsche medicinische Wochenschrift, May 5, 1892.
[2] St. Louis Courier of Medicine, September, 1888.
[3] Wiener medizinische Wochenschrift, No. 12, 1892.
[4] New Orleans Medical and Surgical Journal, September, 1892.
[5] Journal of Laryngology, October, 1892.

current employed, satisfactory results were obtained with a small destruction of the surface and of its glandular elements.

Posterior Nasal Cavities.—Küttner, of Berlin,[1] in an excellent article, considered 50 per cent. a fair proportion of the deaths and recurrences after surgical procedures for the removal of naso-pharyngeal tumors, and reports the results obtained in this class of cases by Grönbeck, by means of electrolysis, showing a decided advantage in favor of the latter method. Indeed, those who are brought in contact with this class of cases will attest to the difficulty of eradicating them. The cold or galvanic snare separates them level from the surrounding normal tissues, under the most favorable circumstances; but, unless the curette be used,—a difficult and dangerous procedure in growths presenting hæmorrhage as a probable complication,—the chances are very great that sufficient pathogenic tissue will be left behind to form the nucleus for a new tumor. Electrolysis, properly applied, with long needles and sufficient intensity to produce active chemical disintegration not only within the immediate radius of the needles, but beyond, on account of the circuitous flux lines, reaches every part of the tumor, involving, in fact, the normal tissues in any way connected with their base. In a case reported by Küttner, for instance,—one of fibrosarcoma, probably the most satisfactory form to treat with electrolysis,—the chief portion of the mass was destroyed in ten sittings, and the small remaining parts in five more, the strength of current used attaining 92 milliampères. Seven months after the operation the naso-pharyngeal cavity remained perfectly free, and the patient has grown strong and healthy. In this case the anode was applied over the breast, and the cathode—an insulated, lance-shaped platinum electrode—was introduced into the tumor both through the pharynx and nose. Had the bipolar method been used in this case, the intensity of the current could have been increased and the area of destruction, on account of the presence of the two needles, further augmented at each sitting, thus reducing their number.

It is probably in this class of cases, as shown by Voltolini, of Breslau,[2] that the method will find its greatest field of usefulness. The sanguinary procedures advocated by the older surgeons, and still resorted to by some, are unwarranted when such a means as electrolysis is at their disposal, and which guilty ignorance causes them to overlook. Almost thirty years have now elapsed since Nélaton[3] proposed and utilized it in these terrible cases, demonstrating its great superiority over all others. But few general surgeons followed him, and we are still treated, in the literature of the day, to the details of such operations as Rouge's, Maisonneuve's, Langenbeck's, Ollier's, etc., which at one time held a prominent place in the field of our resources, but which, in reality, are now applicable in, perhaps, one-fiftieth of the cases in which they are utilized.

[1] Berliner klinische Wochenschrift, November 25, 1889.
[2] Die Krankheiten der Nase und die Nasenrachenraume, etc., Breslau, 1888.
[3] Bulletin de la Société de Chirurgie, p. 559, 1865.

The cases are not wanting in which repeated surgical procedures had been employed in the same case, thus multiplying recurrences, which finally were prevented by electrolysis. To illustrate this, I will take the liberty of incorporating the relation of a case treated by one of the best American specialists, Dr. Rufus P. Lincoln, of New York,[1] in which the tumor had twice been removed by a surgeon:—

"The principal growth was removed from behind the palate in March, 1885, and a tumor that presented in the left cheek from under the zygomatic arch the following September. The tumor re-appeared in the posterior nares, and the first operation was repeated in November. At the time of the first operation the patient could not breathe through either nostril; the soft palate was distended, and the tumor could be seen when looking into the mouth. The patient was deaf in both ears. The left cheek was enlarged by a growth, which he was informed was a part of that in the throat. The patient was conscious of the presence of the tumor two years before the first operation.

"When I first saw him he complained of inability to breathe through his left nostril, and of a sense of fullness in the posterior nares. To inspection there was nothing abnormal visible in either nostril anteriorly. A probe passed into the left, however, met an obstruction as it reached its posterior border; the right was entirely free. On looking into the mouth, the left side of the arch of the soft palate was gaping; it evidently had been once incised and only partially restored. Posterior rhinoscopy disclosed a pinkish-colored mass, of about the size and shape of a horse-chestnut, nearly filling the left half of the post-nasal space. A further examination showed this to be an outgrowth from the left border of the vault and the left lateral wall of the naso-pharynx. To the finger it was immovable, but elastic.

"On the left side, above the first molar, where the mucous membrane is reflected upon the inside of the cheek, a sinus presented, from which a small amount of purulent matter was escaping. A probe introduced here penetrated two inches and a half. It was through an opening made at this point that the zygomatic prolongation of the tumor was removed.

"It was decided at our consultation that an attempt should be made to destroy the tumor by electrolysis. Mr. W. F. Ford prepared for me some needles insulated to within three-fourths of an inch of their points, and of a convenient length, to be used through the anterior nares.

"June 3, 1886. I did my first operation as follows: I introduced two needles well into the tumor, and connected them with the negative pole of the battery. The positive pole was always subdivided, terminating in two large, sponge-covered electrodes, one of which was firmly held against the chest below the left clavicle, while the other was, in a like manner, placed just above the corresponding scapula. After the first treatment

[1] Transactions American Laryngological Association, 1887, p. 219.

but one needle was used. There were, in all, sixteen applications, at intervals of from four to six days, each *séance* occupying from twelve to twenty minutes.

"July 29. All evidence of a tumor had disappeared, the only trace of a growth being a button of cicatricial tissue, which occupied its former site.

"The battery used was that made by the Galvano-Faradic Company, and the number of cells employed at each *séance* was quickly increased to sixteen and sometimes to twenty-two. The immediate effect of the electrolysis was a distension of the mass operated upon and a change of color toward lividity, but both of these changes passed away within twenty-four hours. At each succeeding *séance* the mass was decidedly smaller than at the previous sitting. The only disagreeable symptom besides slight pain was a feeling of dizziness; this never lasted more than half an hour after the operation ended. The patient has been frequently seen since the date last mentioned. There has never been any evidence of a disposition of the tumor to be reproduced. All disagreeable symptoms attributable to the growth have vanished."

The electrical *modus operandi* varies in no way from that already described, excepting that the handle grasping the needles should be a little longer. The two needles, if the bipolar method be used, may either be introduced into the growth behind the palate, this being greatly facilitated by the use of a palate-retractor such as White's, or the passage through the nose and into the pharynx of a couple of pieces of tape, which, drawn out through the mouth, are tied to the ends sticking out of the nose, may thus be made to hold the soft palate and uvula upward and forward, thus exposing the growth.

Cocaine renders this proceeding quite easy and the electrolytic applications painless. No dispersing electrode being necessary in the bipolar method, even the dizziness experienced with the monopolar will be materially reduced if at all present. In certain cases, either the tumor projects into the anterior nasal cavities or the latter are sufficiently spacious to permit the growth to be reached through the nose. In broad, sessile growths more of its surface may thus be penetrated with the needles; in long growths, however, those reaching to or beyond the isthmus, insertion of the needles in their long axis—*i.e.*, through the mouth—will bring about more-rapid results. All forms of neoplasm in the posterior cavity may thus be removed, including adenoid vegetations, which are quite susceptible to electrolytic action.

Pharynx.—In this region electrolysis does not furnish as rapid or as advantageous results as can be obtained by means of other methods, especially galvano-cautery. Grünwald[1] recommends it, however, in chronic pharyngitis, a double platinum needle being inserted into the swollen, irritable spots, and a current of from 10 to 15 milliampères

[1] Deutsche medicinische Wochenschrift, May 5, 1892.

used for from ten to sixty seconds. He was able, he states, to remove all symptoms in one sitting in some cases, the reaction being very slight. No pain was experienced. In extensive local disorders the needle was applied in several places at one sitting.

In the reduction of hypertrophied tonsils, the results so far have not proven very encouraging and are quite tedious.

Larynx.—Much the same may be said of laryngeal affections other than those involving the upper portion of the vocal apparatus. Tumors of the epiglottis, ary-epiglottic fold, and the upper edge of the interarytenoid space can be reached with sufficient ease to permit the introduction of the needles. Lower down, however, the difficulties already alluded to render other procedures more effective.

Electrolysis has recently been advocated by Heryng, of Warsaw,[1] in certain forms of tuberculosis of the larynx. He looks upon the following as the principal indications for its use in this disease: First, hard, diffused, tumor-like infiltrations of the ventricular bands, which cannot be entirely removed by the curette. Secondly, he uses the current to obviate the possibility of dangerous hæmorrhage during the removal of nodules in the same situation; and, thirdly, in chronic affections of the cords with little or no superficial ulceration, the lactic acid not penetrating sufficiently in these cases. In the first and second varieties the author uses a rectangular electrode, the point being introduced from within outward, and in the latter the electrode is stirrup-shaped. For small infiltrations of the epiglottis, etc., he also frequently prefers electrolysis; in these cases, however, he adopts the unipolar method, employing the cathode only. The currents used vary in strength from 20 to 50 milliampères, according to the duration of application. Healthy cicatrization occurred in the majority of the author's cases, and was permanent after cauterization of the epiglottis. Whenever practicable, Heryng prefers operative measures, which he considers will never be supplanted by any other method.

Galvanism and Faradism.

The choice between the continuous and the interrupted current in the treatment of diseases of the respiratory tract should depend upon the nature of the disorder to be treated. The exquisite sensitiveness of the membrane of the anterior nasal cavities renders the use of the faradic or interrupted current painful, while the continuous or galvanic may be borne without trouble. In the larynx, the potent influence of the faradic current on the nervous or muscular elements causes it to induce favorable results much more rapidly than the galvanic, while the pricking sensation experienced seems to be better borne in this locality than in the nose or the pharynx.

Galvanism, which may be obtained from any of the apparatuses

[1] Therapeutische Monatshefte, February, 1893

already described, presents the advantage of being susceptible to mensuration by means of the milliampèremeter. Such is, unfortunately, not the case with the faradic current, a milliampèremeter placed in the circuit of a secondary coil not being in the least affected when the current is turned on. In galvanism we can satisfactorily compute the volume utilized, and therefore indicated in a given case; in faradism we are obliged to gauge the intensity by the sensations of the patient.

Galvanism and faradism involving the application of either or both electrodes to the surface of the skin, a point of importance is thoroughly to moisten the sponge or chamois-skin with which the electrodes are covered to insure penetration. The weak electro-motive force of the galvanic current would otherwise hardly penetrate the skin, while the faradic current would spread itself over the dermic surface. The moist surface of the mucous membranes of the respiratory tract usually supply enough moisture to insure penetration, however, and the electrode applied there requires no preliminary wetting.

For the application of faradism, I have used the J. A Barrett Company's Baltimore chloride-of-silver cell. Its constancy of action and of electro-motive force, its compactness and cleanliness, owing to the absence of acids, have caused me to greatly value this instrument.

Nasal Cavities.—In this location galvanism finds an advantageous application in *atrophic rhinitis*,—a disease in which an unfavorable prognosis may usually be given when any of the forms of treatment generally employed is to be utilized. D. Bryson Delavan, of New York,[1] first described the procedure which had been verbally suggested to him by Shurly, of Detroit, after this author had obtained satisfactory results. Shurly recommended that, in order to obtain the best results the electrode should be made of metal, and that the metallic surface should come into immediate contact with the Schneiderian membrane. Delavan found the use of such an electrode inconvenient, and prefers a piece of common wire around which has been loosely wrapped a pledget of absorbent cotton, the size of the latter being carefully regulated to enable it to accommodate itself to the diameter of the nasal fossa into which it is to be introduced. The negative electrode thus made is saturated with lukewarm water, and, the nasal cavities having been thoroughly cleansed, it is pushed into them until the distal extremity reaches the retronasal space. This electrode may be made in two sections, one of these being introduced into each nasal cavity at the same time. The positive pole is applied to the nape of the neck by means of a flat sponge-electrode, care being taken to carefully moisten the latter. I have observed that the best effects are obtained when all the air in the sponge has been forced out by pressure against the bottom of the vessel containing the water into which the electrode is dipped. The strength of the current recommended by Delavan for the average patient is from 4 to 7 milliampères, and the sittings

[1] Transactions of the American Laryngological Association, 1887, p. 146.

should last from five to twelve minutes, or until the irritation caused by the current has been sufficient to provoke a slight watery discharge.

If a too-powerful current is not applied no disagreeable symptoms will be experienced, the immediate effect consisting of a sensation of warmth, followed by a tendency to increase of secretion. Later in the course of the treatment the symptoms in favorable cases are improved, sometimes slowly, sometimes with a fair degree of promptness.

J. H. Hartman, of Baltimore,[1] reported fourteen cures out of twenty-one cases, the balance being still under treatment at the time, or having failed to continue it. Each case seemed to present its own period at which positive relief was furnished, some improving from the start, others showing no progress for some time.

In *hypertrophic rhinitis* galvanism could hardly be expected to replace, or in any way approach in value, the several measures at our disposal for the treatment of this affection. Recommended by Bosworth eleven years ago,[2] he makes no mention of it in his most recent work.[3] Leute[4] also referred to this method of treating nasal turgescence and engorgement, and considered its action prompt and decided, while Delavan, in the article just quoted, states that he had tried it in "certain cases of hypertrophic rhinitis" and had found it markedly beneficial, and that his experience, as well as that of several colleagues to whom he had recommended it in consultation, had encouraged him to regard it as a decided acquisition to the therapeutic resources at our command. The method of application does not differ from that recommended in the treatment of atrophic rhinitis.

In *hay fever* galvanism has been recommended by Hutchinson, of Providence,[5] but, from a study of the case and its results, it appears evident that the time it took the author to relieve his case corresponded with the time it had still to run, no value, therefore, being attachable to the treatment. In a case of hysterical sneezing, however, Solomon Solis-Cohen, of Philadelphia,[6] obtained satisfactory results by means of daily applications of the continuous current, the positive electrode being inserted into the nostril and upon a sensitive spot located on the septum, the negative on the cheek. Five Daniell's cells were first used, this number being gradually increased to 20. The length of the sitting was at first one minute, and was increased to five minutes. Intense pain was at first experienced, but this was gradually diminished until after two weeks, when the 20 cells caused no suffering. The presence of hysteria caused Cohen, however, to look upon the case with some degree of suspicion.

In the treatment of other neuroses of the nasal cavities—*anosmia*,

[1] Transactions American Medical Association, 1888, p. 84.
[2] New York Medical Record, September 16, 1882.
[3] Diseases of the Nose and Throat. New York, 1889.
[4] Medical Gazette, 1882, p. 471 (quoted by Hartman).
[5] Boston Medical and Surgical Journal, November 5, 1874.
[6] Transactions American Laryngological Association, 1886, p. 151.

parosmia, etc.—much benefit is not to be expected if the disorder of smell present has lasted more than two years. Beard and Rockwell[1] and Althaus[2] have recommended galvanism, but the latter, in utilizing powerful currents, caused his patients considerable suffering. A weak current, on the contrary, beginning with 1 milliampère and gradually increasing in strength according to the patient's sensations, will be productive of much better results, especially if administered in conjunction with strychnine internally. The negative pole of a small flat probe, covered with cotton-wool and moistened, should be applied over the olfactory area, the positive over the brow, both electrodes being carefully moistened. No sensation will at first be experienced, but as the ampèrage is gradually increased the current soon makes itself felt. The *séances* should be short at first, then gradually increased. After some weeks, when the patient has become accustomed to the galvanic current, the faradic may be employed,—using the weakest current the battery affords at first; then, as was the case with the galvanic, gradually increasing the strength. When using the faradic current the positive pole should rest against the back of the neck. Daily applications are necessary. It is needless to say that a careful search for the cause of the trouble and the proper treatment thereof are inevitable adjuncts of the electrical treatment.

Pharynx.—In *atrophic pharyngitis*, as well as in the corresponding disorder of the nasal cavities, galvanism, recommended in 1880 by Shurly, of Detroit,[3] obtains more durable effects than any form of treatment. Shurly recommends that the membrane be first washed with a solution of common salt, then anæsthetized with a 4-per-cent. solution of cocaine. After five minutes the electrodes (small, elongated rheophores) are applied, one through the nasal passages, the other to the posterior and lateral wall of the pharynx, moving them both rapidly but quietly over the surface, being careful to keep them closely applied. The battery used consisted of 2 cells, gradually increased to 4 or 5, of the Leclanché pattern. The electrodes should not be covered unless, as in purely nervous cases, it is desired to apply one of the electrodes to the side of the neck. "Gagging and muscular movements require the removal of the instruments after a few seconds for a short period of repose, when they are reapplied, perhaps four or five times, according to the tolerance of the patient and the sensible effect produced. The *séance* may be repeated two or three times a week, as may seem advisable. I have experienced the greatest difficulty from the intolerance of the parts in question to the manipulation, but, as before mentioned, the use of cocaine has afforded, in the majority of cases, the desired tolerance. However, as might be expected, the drug, to a certain degree, antagonizes the effect of the galvanic application, and must be compensated for either by a longer or more

[1] Medical and Surgical Uses of Electricity. 3d ed. London, 1881.
[2] London Lancet, 1881, p. 772.
[3] Transactions American Laryngological Association, 1880, p. 20, and 1885, p. 1.

frequent manipulation. In some cases one thorough treatment a week will prove sufficient."

The difficulties so frankly recognized by Dr. Shurly forming quite a drawback in the treatment of the cases I was called upon to treat, I modified the procedure by utilizing water as a conductor and using a Morell Mackenzie electrode to convey the negative current to the water. The pressure of the fluid causes no gagging, thus rendering cocaine unnecessary. The tissues being in no way touched by the electrode, the full benefit of the current was obtained by the mucous surfaces without involving any undesirable results of actual contact with the instruments.

The positive electrode is placed over the thyroid cartilage, the

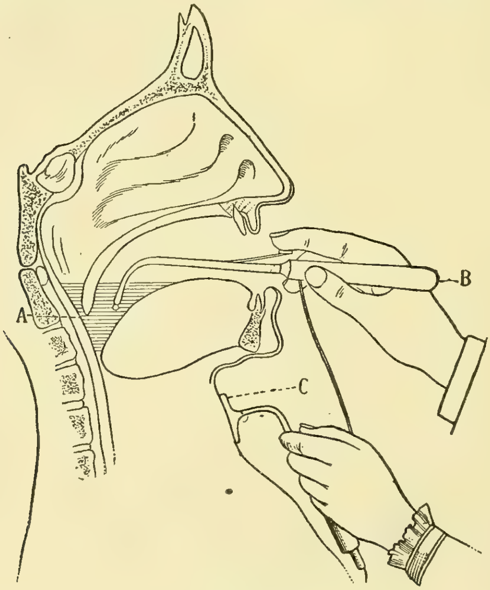

Fig. 13.—Author's Method of Applying Electricity to the Pharynx.
A, water; *B*, Mackenzie laryngeal electrode transmitting negative current to water; *C*, positive electrode.

handle being bent, as may be seen in the cut, to enable the patient to hold it himself, and out of the way of the operator's hand. The procedure is as follows: The patient having taken what is usually called a mouthful of water,—in reality, about an ounce,—he is told to throw his head backward and to open his mouth. The first movement of deglutition causes the water to fill the pharyngeal cavity. Light being thrown in, the Mackenzie electrode is introduced and simply immersed in the water, the external electrode, thoroughly wetted to secure penetration through the skin, being placed over the thyroid. The current being then closed by pressing the button of the Mackenzie electrode, it is allowed to flow as long as the patient can hold his breath. The mouth-electrode being then taken out, he can, either by closing his mouth and bowing his

head forward, bring the water forward and take a few breaths through the nose, then renew the first movement, throwing the head backward, etc., or take another mouthful of water, after ridding himself of the first draught. The oftener the sittings—which should last at least fifteen minutes—are renewed, the better; and if no irritation of the membrane follow the application, they may be renewed every day; or the patient may be taught the *modus operandi*, and he can then treat himself twice or three times daily at home.

Shurly states that his method of applying the current causes the membrane to assume a vivid color and to be bathed in a quite-fluid secretion for a number of hours after the application, the inspissated secretion diminishing materially. In the modification I have described the results differ somewhat, the tendency being more toward a disappearance of the parchedness and of the burning after a certain number of applications. Faradism has proven more promptly effective than galvanism in the single case in which the former was used.

Soft Palate.—Paralysis of the soft palate is not an unusual result of diphtheria and other infectious disorders. Besides the internal treatment indicated, the measures just recommended for atrophic pharyngitis may be advantageously applied.

Larynx.—It is, of course, in the motor affections of this organ that electricity becomes of use, faradism being far more effective than galvanism. It must be said, however, that the likelihood of cure corresponds with the degree of amenability to treatment of the original cause. Whether it be syphilis, tuberculosis, aneurism, a cerebral neoplasm, etc., local treatment is absolutely subservient to that of the primary affection, and the treatment of the latter, which does not require elaboration here, is, therefore, the first indication. This done, measures must be adopted to stimulate the laryngeal muscles to action, faradization for this purpose surpassing all other means. The laryngeal electrode (Morell Mackenzie's) shown on opposite page may be advantageously employed for the negative current, the dispersing positive electrode being applied over the thyroid cartilage. Both should be covered with sponge or kid, to prevent the stinging sensation experienced in the larynx when this precaution is not taken, and thoroughly wetted to insure penetration.

The manipulation of Mackenzie's electrode is like that of an ordinary laryngeal forceps, the mirror being employed to note and conduct the localization of the tip of the electrode. The nearer the application to the paralyzed muscle, the better. The electrode being in position, the finger-rest on the top of the handle is depressed, and firm pressure is exerted on the neck by the other electrode. At first this manipulation is quite difficult to perform, gagging and retching preventing the introduction of the instrument. After a few trials, however, the parts become more tolerant, and the application can be borne, in the majority of cases, without trouble. Cocaine anæsthesia may be used in difficult cases; at

least, the first few sittings. Each application of the current should last but a few seconds, and be repeated several times at short intervals. One sitting every day should be obtained, if possible.

The current may also be applied by placing one pole on each side of the neck, externally. This method is very inferior to that just described. Better than it is electrical massage, which is carried out by placing the positive pole, thoroughly wetted, on one side of the larynx, and the fingers of the opposite hand (that holding the negative pole and in contact with the sponge) on the other side. The fingers, having become the conductors, are moved up and down and pressed into the surface of the neck, in the manner practiced by masseurs. They must also be kept wet by occasional immersion in water.

In the treatment of hysterical aphonia the method just described, and especially that illustrated on page 34, may be employed. Response to such treatment often occurs at once; in some, however, nothing seems to cause return of the normal voice,—most probably because of atrophy of the paralyzed muscles.

OPHTHALMOLOGY.

By L. A. W. ALLEMAN, M.A., M.D.,

BROOKLYN, N. Y.

When one undertakes to review the field of electro-therapeutics in ophthalmic practice, and set down the well-established facts and those which seem most likely to stand the test of further investigation, one is struck by the indefiniteness of our knowledge of the subject. But, because little can be said which we may hope will be final and authoritative, we should not be discouraged and abandon the work as unprofitable, for we gain many facts which are suggestive, new channels for investigation constantly open up to us, and, the more we examine critically and impartially the evidence before us, the more hopefully we return to the work, confident of brilliant results, if only we are content to investigate not as partizans, but as students, and to record the results of our labors fearlessly and honestly. This is not always as easy a task as it may at first appear. The use of electricity, especially in ocular therapeutics, has most unfortunately fallen largely into the hands of charlatans, and therefore the profession is too apt to look with suspicion upon any one who seems to be an enthusiastic admirer of this method of treatment. This has at least one advantage; the student who wishes to command the attention of others to the results of his investigations must do so by backing up each statement with full details of method, and guarding most carefully every avenue through which inaccuracy could creep in. When this is done it will be unnecessary to go over and over again the same ground before we can feel that we have a firm basis of fact to build upon.

Quite enough work has been done already to settle many of the disputed points, had these observations been recorded with sufficient care. It is not at all unusual to read a case-report which merely states that "electricity was employed" in a given case "with apparent benefit," or that "electricity was tried, but proved of no avail." It is perfectly evident, to any one who has given the least attention to the subject, that the choice of poles, the strength of current, and the duration of treatment are not matters of indifference; and unless these details are mentioned, and are supplemented by sufficient evidence to show that care was used to avoid the ordinary sources of errors, one can always have grave doubts whether the successes were more than coincidences, and whether the failures were due to the agent used or to the method of its employment.

In the treatment of diseases of the eye it is not wise to use very powerful currents, and, as the sensations of the patient furnish a most

imperfect guide, it is of the utmost importance that the operator should be provided with an instrument that will indicate, with sufficient accuracy for clinical purposes, the current which is being given. Such instruments are described in Section A, to which the reader is referred. Besides a milliampèremeter, a rheostat is also of great utility. Many of the instruments in general use are not adapted for regulating to a nicety the small currents used on the eye, and I would suggest the instrument shown in Fig. 1, which I have found extremely satisfactory. It is a modification of one made by Mr. Barrett, and is identical with it in principle. The resistance is furnished by a pledget of cotton, with which as much powdered graphite as possible has been incorporated. This rests between two metal plates, the bottom one being connected with one binding-post; the upper, through the screw at the top, with the other. By turning the thumb-screw the upper plate is approximated to the lower, and the cotton, thus subjected to greater pressure, offers less resistance to the passage of the current. The instrument works very

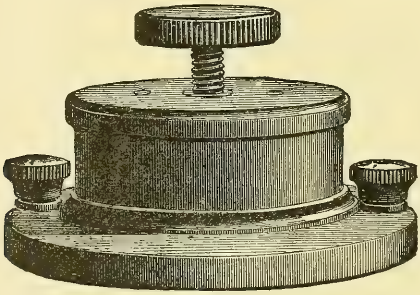

FIG. 1.

smoothly and is extremely sensitive, occupies little room, and does not readily get out of order. I have found that, the longer it has been in use, the more steady and sensitive it becomes, probably because the cotton is more firmly packed by use, and thus an evenly-diminishing resistance takes place under pressure.

The battery to be employed will depend largely on the convenience of the operator. If one wishes to use the same instrument for office work and for treating patients at their homes, some dry-cell battery—as, for example, the small chloride-of-silver cell—will be most convenient. For a stationary battery any reasonably-constant cell may be employed. I use a battery of Le Clanché cells, and have found it to answer admirably.

When the application is to be made directly to the cornea or sclera, an electrode designed for this purpose is a convenience; but when not at hand the finger of the operator may be used as a substitute. The electrode shown in Fig. 2 has proved very satisfactory for the purpose. It consists of a small bar of silver insulated by a hard-rubber shell,

save at the lower extremity, which is seven millimetres in diameter. The tip screws into a collar that is attached to a coil of insulated wire, which acts as a spring in breaking the force of the impact upon the cornea and allows the angle of the tip to the handle to be changed at will. A wire conducts through the hard-rubber handle to a binding-post at the top.

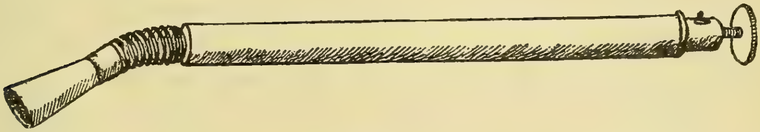

FIG. 2.

For the closed lids or cheek I use an electrode shown in Fig. 3. This is a disc of carbon, about an inch in diameter, to which is attached a metal upright. This fits into a hard-rubber shell (A) and is fastened by a screw (B). The disc is covered with a small pledget of cotton, and after it is thoroughly wet it is attached to the rubber and clamped. The cotton can be changed for each patient, and so has the recommendation of cleanliness. The absence of a long handle is of advantage when the eloctrode is held by the patient upon the cheek while the operator is

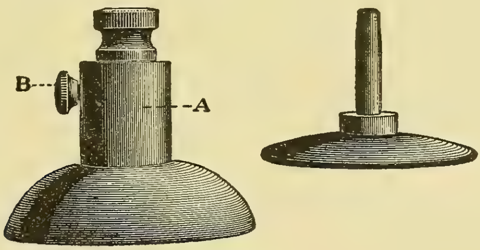

FIG. 3.

making an application to the cornea, and also when used upon the closed lid the smaller electrode is held more conveniently, and is less likely to be too firmly pressed against the globe.

DISEASES OF THE LID AND CONJUNCTIVA.

Tumors of the Lid, etc.—The skin of the lids suffers, in common with that of other parts of the body, from diseases amenable to electrical treatment. For the removal of benign tumors and telangiectasis the use of electrolysis seems especially indicated. For the further consideration of this subject the reader is referred to the section on "Diseases of the Skin." The electrolytic needle connected with the cathode has been used for the removal of chalazions, and it is alleged that the contents will escape readily through the track of the needle, and that sufficient stimulation is excited to produce an obliteration of the sac. When, after a succession of styes, or a chalazion, an annoying thickening

of the lid results (which in some cases is so marked as to amount to a positive deformity), the galvanic current is indicated for its removal. A convenient method of application is to grasp the thickened portion with a pair of dressing-forceps and make them the cathode, passing a current of 2 milliampères for two or three minutes.

Partial Trichiasis.—When we have only to deal with a limited number of cilia, which, growing in a wrong direction, are irritating the eye, electrolysis offers the most satisfactory method of removal. Michel, of St. Louis, first suggested this method, and it has substantiated its claim to our acceptance. The destruction of the hair-follicle is accomplished in the following manner: A fine needle is inserted as closely as possible to the hair to be destroyed, passing it well beyond the root of the hair and taking care to give it such an inclination as to insure its passing through the follicle. The needle is connected with the cathode and the anode placed on some convenient spot on the cheek, or near the outer canthus. After the needle is in place the current is closed at the battery by an assistant, and the needle held in position until the tissues in its immediate vicinity look white and small bubbles of gas are seen. The needle should then be withdrawn, and the hair, which is well loosened, can be removed; it should come away easily and bring with it a small mass of tissue at its extremity. If the hair be not perfectly loosened, the operation should be repeated. A current of 4 to 5 milliampères may be employed; the stronger the current, the less time is required to complete the destruction of the follicle. The chief disadvantage of the method is the pain attending it. The free use of cocaine may render the insertion of the needle quite painless, but when the current is applied the patient always complains of much pain; still, these cases are usually so distressing that the patient is willing to submit to any operation which promises permanent relief. Many needles intended for this purpose have an arrangement for closing the circuit, but I have not found this of advantage. It is at best a difficult matter to hold the needle steadily in place, as the lid is constantly twitching, and any shifting of the instrument in the hand necessary in closing the circuit is apt to withdraw it slightly, and thus prevent the attainment of the desired result. It is much more convenient to have the circuit closed at the battery, or, if an assistant be not at hand, the patient can do this by applying the anode when directed. Little reaction follows the treatment, and it is favorably reported by those who have used it extensively. Mr. Arthur Benson reports one hundred and twenty cases, and is enthusiastic in his commendation of the method.

Herpes Zoster.—In herpes zoster the action of the galvanic current is most highly lauded. Nagel and Driver both recommend it, and Dr. Arthur Mathewson reports a series of cases in which the result was all that could be desired, both in relieving the most distressing pain and in hastening the favorable termination of the disease. Dr. Mathewson in-

forms me that his subsequent experience confirms him in his good opinion of the treatment. He found no special difference in the action of the poles, and uses a current of just sufficient strength to produce a slight sensation of warmth on the part of the patient. This disease seems to be one of the instances in which there can be no question as to indications for the employment of the current.

Granular Conjunctivitis.—Among the myriad remedies which have from time to time been proposed for the cure of this most tedious and troublesome affection electrolysis has found a place, and, when employed by the application of an electrode to the surface of the granulations, is probably about as useful as most astringent and caustic remedies which are commonly employed. With a more rational application, developed by a consideration of the pathology of the disease, it promises to be one of the most valuable methods at our command. In the use of electrolysis, as in any of the surgical procedures recommended in the treatment of granular lids, one point should be kept well in mind. The danger in these cases, the goal to which they all more or less rapidly tend, is a final stage of scar-formations, cicatricial contraction, and atrophy. All treatment, therefore, which involves destruction of tissue will, in its final result, prove disastrous; and in the application of electrolysis care should be employed not to overstep the limit of inhibiting the nutrition of the granulations, thus producing a tissue destruction which shall hasten an ultimately bad result.

Geo. Lindsay Johnson, of London, has obtained good results from the treatment of trachoma by electrolysis combined with scarification. His method of procedure, in cases of trachoma before cicatricial changes have set in, is as follows: The patient being thoroughly anæsthetized, the lid is everted over a hard-rubber spatula; the conjunctiva, held firmly by a hook, is put tightly on the stretch; while the lid is held in this position, a three-bladed scarifier is drawn along parallel to the lid-margin, the cut being made by a finger motion, care being taken to make the incision sufficiently deep at the extremities of the cut. The last cut being used as a guide, parallel incisions are continued as far as possible toward the retrotarsal fold. The depth of the incision is regulated by a guard on the instrument, which is set at from two to four millimetres, the rule being, the thicker and more engorged the parts, the deeper the incision. Considerable bleeding may follow, which is controlled by pressure with cotton pledgets. This completes the first step of the operation. The next step is passing the electrolyzer through the incisions. This instrument consists of two platinum blades in a handle; with this electrode the track of the incisions is carefully followed, the grooves being taken in turn and opened up along their entire length. A current of 30 milliampères is employed. The author remarks that he has used currents of varying strength, and thinks a strong current should be avoided. He would put as a limit a current of 50 milliampères. (I think few will dis-

pute his statement that this current should not be exceeded.) Stronger currents produce too much reaction and cause sloughing of the cornea. The writer asserts that he has never seen any abnormal curvature of the lid result as a consequence of the operation.

I should, however, much more readily incline to the method of treatment advocated by Dr. T. D. Myers, as more rational, safer, and easier of application. This, too, is a process of electrolysis, but no scarifier is employed, and the granulations are destroyed by a fine needle. The treatment is based on a consideration of the pathological condition which it is intended to relieve. There are, according to Myers, two conditions to be met. The first is to remove from the tissues the micro-organisms which are a part of the morbid condition without permanent injury to the normal conjunctival structures; the second is to relieve the excessive nutrition which, even were no micro-organisms present, keeps the lid in an abnormal condition. Dr. Myers says: "Tried upon these lines it is clear that none of the usual plans of treatment that have heretofore been employed can be expected to succeed with certainty. It may be an easy matter to burn out the granulations with caustics, and at the same time to destroy the usefulness of a large area of the conjunctiva, or to follow the example of some very bold, and I may add very bad, surgeons, who have extirpated the entire conjunctiva to get rid of these granulations; but it is an entirely different proposition to successfully treat the disease while preserving the full integrity of the conjunctival membrane. It is equally useless to expect permanent cures from a purely antiseptic plan of treatment, for these reasons: While it may be admitted that it is possible by these means to kill the bacteria, antiseptics cannot interfere to any degree with the process of overstimulation taking place in the fixed-tissue cells; and this process can go on indefinitely, when it is once started, without the aid of micro-organisms. If the antiseptic acts by coagulating the albumen in the bacteria, as is quite possible, the use of a soluble substance for this purpose is open to the objection that, when employed in sufficient quantities to kill bacteria, it becomes dangerous to the albuminoid constituents of the normal structures, as its action in the tissues cannot be controlled."

With a delicate platinum or iridium needle the supply vessel of the granulation is followed back to its source of origin and the base of supplies thus cut of, and it is possible "to coagulate and remove the entire contents of a small sac, and thus render antiseptic the most likely lurking-place of the micro-organism." He employs a current of $1\frac{1}{2}$ to 2 milliampères, as found to be best suited to the condition. When compared with the 50 milliampères used by Johnson, this does indeed seem like mild treatment, but I should feel far more confidence in the ultimate good result. The lid is anæsthetized with cocaine solution, or, if particularly sensitive, with $\frac{1}{48}$ grain of the solid salt; after the use of the needle the coagulum is washed away with a saturated solution of boric acid. There

is little or no reaction, and the pain is at no time considerable. The reported results in cases treated by this method are very encouraging, and it is worthy of a careful trial.

Diseases of the Lachrymal Apparatus.

Stricture of the Canaliculus and Duct.—This very annoying trouble is one in which the methods of treatment commonly employed are not entirely satisfactory. The slitting up of the canaliculus and the probing of the duct are not always attended with as permanently satisfactory results as could be desired ; and we naturally welcome any improvement in our methods of treatment which promises better results. In a paper on the subject of closure of the canaliculus by Stevenson and Jessup, in the *British Medical Journal*, the advantages of the use of electrolysis in these cases are very forcibly pointed out. A small probe is introduced into the punctum, and passed along to the nasal duct; one made of platinum has been employed by the writers, and the handle is shown in which it is inserted. (This, although no doubt convenient, may be dispensed with. I am in the habit of connecting my cord directly to a small lachrymal probe.) Great stress is laid upon the use of the cathode, as serving to melt down and dissolve the obstruction which it is desired to remove.

The probe being in place, a current of 2 to 4 milliampères is applied. With a current of 4 milliampères thirty seconds suffice for the operation; with a weaker current more time is necessary. During the operation a little froth collects by the side of the electrode and oozes out of the punctum; after a few seconds the probe, which is at first grasped tightly by the canal, becomes sufficiently loosened to move backward and forward with ease. In a few instances when the anode was used by mistake, an opposite result followed,—the tissues seemed to be dried, the pole was more firmly grasped, and the reaction was also much more considerable. No anæsthetic was employed, and no very considerable pain was complained of, a slight burning sensation being remarked by the patient, but not seriously objected to. Ten cases are reported, results all being satisfactory, permanent cure resulting after a few applications. No probes larger than one and one-half millimetres were employed ; care was exercised to keep the probes away from the eyeball.

The neighborhood of the punctum, inner canthus, and the surrounding integument for about an inch remained slightly congested for a couple of hours after the operation. The advantages of the treatment are thus summed up by the writers: "Advantages attending this procedure are chiefly due to the fact that so little displacement or alteration of the normal channel is effected ; we have by it the means of increasing the lumen of the punctum of the canaliculus without any excessive stretching, which must necessarily alter the condition of the surrounding muscular and other structures."

I see no reason why this treatment, which seems so efficient in obstructions of the upper part, should not work equally well for strictures situated farther down the canal. From a limited experience, I am inclined to think that it will prove very efficient for the removal of any save bony obstructions. Sometime since I saw the statement that a urethral sound, when made the cathode with a weak galvanic current, could be passed without pain. It seems reasonable, if this be true, that the same expedient might be employed in the passage of a lachrymal probe, and advantage taken both of the relief of pain and the electrolytic action of the current. On the few occasions on which I have had the opportunity to try this, it has seemed to me that the operation was less painful than usual. A current of not more than 1 milliampère must be employed, and after the probe is in place the current-strength may be increased if desired.

Diseases of the Cornea.

Keratitis.—Mr. Benson is cited by Althus as recommending the galvanic current, in cases of "strumous keratitis," for the relief of the photophobia; he has placed on record thirty-two cases so treated. His method is to place the cathode on the supra-orbital foramen and the anode on some part of the face. I have in a few cases been able to verify this statement, and have seen the blepharospasm and pain most markedly relieved by a current of $1\frac{1}{2}$ milliampères for five minutes. Liebig and Rohé give a case, reported by Lewandowski, of reflex blepharospasm, in which the spasm of the orbicularis and corrugator followed ten days after a sabre-cut of the left cheek. The spasms were severe and constant; a single sitting with galvanization of the medulla oblongata, anode to back of neck, cathode in the hand, relieved the spasm perfectly.

Erb mentions the experiment of Arcolio, whom he reports as obtaining good results, in "parenchymatous and epithelial keratitis," by the use of the faradic current. The positive pole is placed on the nape of the neck or in the hand, and the negative, in the form of a small sponge or camel-hair brush, directly on the surface of the cornea, or by means of a large sponge to the lower lids. Sittings should last from five to eight minutes daily. Erb found the galvanic current of service in keratitis associated with the paralysis of the trigeminus. ("Cathode stabile and labile on closed lids, 6 to 8 Stöhrer cells.")

Opacities of the Cornea.—The galvanic and faradic currents have from time to time been employed in the treatment of opacities of the cornea, but have not until recently commanded the confidence of the profession, and have not occupied that prominent place in the therapeutics of these unfortunate cases to which they seem to be justly entitled. Before the discovery of cocaine the direct stimulation of the scar was scarcely possible, and when the application was made to the closed lid the mild current, which is necessitated by the delicate organ under treat-

ment and the proximity of the cerebral structure, was not sufficient to bring about the stimulation necessary to produce a marked and rapid improvement. However, favorable results were from time to time reported. Dr. C. H. H. Hall, U. S. N., has published several cases in which he obtained especially gratifying results, and no doubt if the treatment be persevered in these cases could be much improved by application through the closed lids. The use of cocaine has, however, much simplified the task, and has enabled us to make the treatment of the greatest practical value. I have treated a very considerable number of these cases, and have been more and more impressed with the value of galvanism, and Adler has lately reported very happy results from a similar method of treatment. The whole secret of success is in producing sufficient stimulation of the scar to bring about its gradual absorption and the deposit of clear corneal tissue, and in stopping just short of an irritation which shall produce active inflammatory conditions with stasis and a destruction of tissue. The duration of the opacity seems to have little to do with the prognosis, save that too recent cases do not progress as favorably, being more prone to severe inflammatory reaction. The improvement will, of course, depend largely on the nature of the case. Dense white scars yield very slowly to treatment while superficial opacities disappear with wonderful rapidity. In the cases of adherent leucomata with dense scars the centre of the scar will require a longer time for its absorption, and it may not be advisable to continue treatment till all opacity disappears; but in cases which have persevered I have obtained very good results in clearing, and no unpleasant irritation was occasioned by the incarcerated iris.

The clearing always begins at the margin of the scar, and consequently, when the scar is excentric to the pupil and vision obscured by the edge of the opacity, visual improvement is very marked from the first. When the centre of the scar is directly over the pupil, little visual improvement will be obtained till late in the treatment. During the application of the current the conjunctiva becomes injected and fine vessels are often seen running on to the cloudy area. They disappear soon after the application, and their presence is a very encouraging sign of progress. At each sitting the eye flushes a little more easily and the progress of the clearing can be readily followed by noting the diminishing area of the unvascularized scar. The results obtained have been most encouraging.

I have endeavored to test thoroughly the advantages of the method, and have tried, as far as possible, to avoid such errors as might arise from careless observation, by using an artificial illumination of uniform brilliancy for all the visual tests, an inelastic measure in testing vision at less than twenty feet, using different test-letters at different sittings, and occasionally returning to the original card. I have stopped treatment for a time, and found the condition of the scar and vision to remain

unchanged and the improvement to begin again immediately upon renewal of the treatment.

From the observation of a number of cases extending over some considerable time, I am convinced that the use of electricity promises the most efficient and, in many cases, the only treatment of avail in opacities of the cornea of long standing. In making an application the operator stands behind the patient, whose head is thrown back in a reclining-chair. The anode is given to the patient, who is directed to press it against the cheek on the same side as the eye to be treated. Then place the binding-post of the eye electrode against the patient's tongue, and turn the rheostat until the needle indicates the strength of current it is desired to use; then place the electrode upon the cornea, which has been anæsthetized by the previous instillation of cocaine. The rheostat is intrusted to an assistant, who carefully watches the needle of the milliampèremeter and, by turning the screw of the rheostat, maintains a uniform current during the application. With the thumb and first finger of the left hand the lids are separated sufficiently to prevent their coming in contact with the electrode, since a current easily tolerated by the cornea is painful and irritating when passing through the margin of the lids. The electrode is held with the right hand, gently, in contact with the cornea, and careful watch is kept during the application that the contact is not broken nor too firm a pressure made against the cornea.

It is, perhaps, unnecessary to test the current by first passing it through the tongue, which offers practically the same resistance as the eye; but, as there is always the possibility that by some accident the rheostat or milliampèremeter may be out of order or short-circuited, I think it safer to first try the current upon the tongue, when, if it is too strong, the patient will quickly inform you. The cathode is applied to the cornea, being theoretically indicated for the stimulation we wish to produce. The strength of current that may be safely employed varies widely in different cases. I begin treatment with $\frac{1}{2}$ to 1 milliampère for one minute; should this be easily borne, I gradually increase the time up to three or four minutes, which is about as long as it is possible to hold the electrode in contact with the cornea without fatigue. The strength of current may be slightly increased at each application, until the patient's point of tolerance is reached. I place, as the limit in any case, a current followed by a slight irritation, which shall subside before the next application, which I usually make after an interval of one day. The strongest current that I have employed is 4 milliampères for three minutes; but I do not think any better results were obtained by this than by a smaller current repeated at more frequent intervals.

A current of 4 milliampères will only be borne in exceptional cases, and 1 to $1\frac{1}{4}$ will, I think, give the best results. With this current considerable irritation is sometimes experienced at the anode by thin-

skinned people. I have frequently produced marked vesication on the cheek without setting up any disturbance of the cornea.

Diseases of the Crystalline Lens.

Cataract.—In the whole field of ophthalmic surgery, there is no disease which has received more careful consideration than cataract. Although the surgical treatment of this disease is now attended with the most gratifying success, some method by which the progress of senile cataract could be arrested has been most eagerly sought.[1] To timid patients the operation itself seems a most trying ordeal, and, after the successful removal of the lens, the loss of the accommodative power and the absolute dependence of the patient upon glasses are most undesirable.

Another unfortunate feature of the disease is the unavoidable period of blindness which often elapses between the loss of useful vision and the maturity of the cataract. Since cataract seems to be due to a failure of nutrition of the lens, we would naturally expect it to be one of the diseases most especially adapted to treatment by the electrical current; yet we are forced to admit that, thus far, all attempts in this direction have been attended with negative results. From time to time most enthusiastic reports of cures by this method have appeared in medical literature, and, as it is probable that this experience will be repeated, we should be upon our guard, and subject such claims to a most critical examination. If we bear in mind some facts as to the natural history of cataract, we shall be less likely to be deceived by the alleged cures which are constantly being presented for our acceptance.

A beginning cataract is very frequently complicated by some disease of other portions of the light-receiving apparatus, and an improvement in vision may result from a favorable progress of the complicating disease, while the condition of the lens is unimproved or even worse. Swelling of the lens and the unequal involvement of different portions of it sometimes cause, at the outset, considerable loss of vision, and it not infrequently happens that as the disease progresses the vision will, for a time, show considerable improvement; such cases will, of course, lend great encouragement to any method of treatment that may have been employed, at the time when the improvement would naturally have occurred. Again, lenticular opacities are not at all uncommon late in life, and they are by no means always progressive, It is an every-day occurrence to meet with patients in whom the opacity has remained stationary for many years; it is, therefore, manifestly fallacious to claim, for any method of treatment, that it has arrested or removed incipient

[1] In the "Life of Peter Van Schaack," an American refugee during the Revolution, it is related that in 1780, while in London, he consulted John Hunter on account of a cataract, and that Mr. Hunter dissuaded him from an operation, upon which he was determined, and advised him to take treatment by electricity from Mr. Birch, in Essex Street, the result of which, unfortunately, was negative.

cataract, unless a very large number of cases are reported in which the progress of the disease has been watched for a long time, unless the visual improvement is attended with a corresponding improvement in the ophthalmoscopic picture, unless all the records are made by a skilled observer, and unless the greatest care is exercised to exclude such errors as may arise from the natural progress of the disease and from careless observation. It is a wise precaution for any one, who may believe that he has discovered some treatment of avail in this disease, to submit his cases to some competent and impartial observer, who shall carefully watch and record their progress. In my experience, I have not found electricity of any avail in the treatment of uncomplicated senile cataract, but I do not feel that we are justified in saying that further experimentation may not be attended by more happy results.

Diseases of the Iris.

Iritis.—In the acute stage of iritis the use of electricity is of doubtful benefit. In some few cases I have seen the pain and congestion relieved by the application of the anode to the closed lids with a current of 1 milliampère for two or three minutes, but it will often prove of no avail. In clearing up a hæmorrhage from the iris, the employment of galvanism is indicated; here the cathode with 1 to $1\frac{1}{2}$ milliampères should be employed. I have had the most satisfactory results from the use of the current in cases of adhesions and inflammatory deposits following an iritis. It is well, where the use of atropia is not for any reason contra-indicated, to use it conjointly with electricity. I have seen the most happy results, in the breaking up of adhesions and in vision, follow this procedure. The cathode with a current of, say, 2 milliampères for five minutes through the closed lids is most effective, and produces no reaction.

Diseases of the Sclerotic.

Episcleritis.—This disease is at best a very stubborn one, and the results of any treatment will often prove most discouraging. Still, I think we may reasonably expect some benefit from the use of galvanism. I have seen the pain much relieved and a favorable outcome of the trouble apparently hastened by its employment. I have used it both through the lids and directly on the sclera, and find the latter method preferable. I have used the anode on the eye, and have gradually increased the current from $\frac{1}{2}$ to $1\frac{1}{2}$ milliampères for three minutes, episclerally.

Diseases of the Vitreous Body.

Opacities.—The electrical current has been employed with much success in clearing up opacities of the vitreous, and theoretical considerations, as well as experience, sanction its employment. Girard-Teulon states, as a result of his investigations in this matter, that the

electrical current is the most effectual and also the most rapid remedy in the treatment of vitreous opacities. He applied the anode with 8 to 10 Daniell cells on the closed lids, the cathode behind the ear, two to four minutes. Little reports favorable results from the use of the faradic current. In his experience, the cases treated by a weak faradic current make more rapid progress than those in which internal medication is alone employed. His experiments were confined to vitreous opacities due to changes in the choroidal or retinal circulation. It would, however, in his opinion, be valuable in any form of hyalitis, and he suggests its employment in cases of vitreous opacity from the intra-ocular changes of myopia, and in those due to the presence of a foreign body, believing it possible, in this way, to clear up the vitreous sufficiently to locate the foreign body. Two to three weeks were usually sufficient, applications being made every other day, one pole applied to the eye, the other being held in the hand or at the nape of the neck.

Not only have both the galvanic and faradic currents been employed with success, but the galvanic current has been employed in widely-different methods. Le Fort places the electrodes connected with only two cells on the temples, and allows them to remain day and night. Some apply the anode, others the cathode, to the closed lids, and all report good results. From these facts Erb concludes "that not much depends upon the direction of the current, or upon which pole is applied to the eye, but that it is only essential to let the current flow through the eye." He, himself, recommends that the current should be passed from the closed lids to the nape of the neck, the current being reversed so that each pole may act upon the eye at each sitting, or that at one sitting the cathode and the next the anode should be employed. Weak currents and sittings of two to eight minutes are advised. This is surely one of the instances where we may hope that careful observation may bring some order out of the chaos and establish the definite therapeutic value which electricity undoubtedly possesses in this disease.

Diseases of the Retina.

Retinitis.—In hæmorrhagic retinitis the galvanic current may be employed with the reasonable expectation of clearing up the hæmorrhages and of preventing recurrences. In diabetic retinitis, with or without a central scotoma, it is especially indicated. In a case of diabetic retinitis of very long standing, in which a succession of small hæmorrhages had most seriously interfered with the patient's vision, I succeeded in absorbing the old hæmorrhages and preventing the recurrence of new ones by the use of the galvanic current. As the patient had been under observation for a year or more before this treatment was instituted, and as the medical and dietetic treatment was not changed nor any other improvement in the patient's condition noticed, at this time, I thought it fair to conclude that the happy result was due solely

to the electrical treatment. In a few cases subsequently treated I have seen a diminution or disappearance of the central scotoma and a marked visual improvement while under treatment, and the method seemed worthy of further trial. In the cases treated I used a current of 1 to 1½ milliampères, with sittings two or three times a week, of five minutes each; cathode to the eye. In albuminuric retinitis I have not seen so happy results, bnt as my observations have been limited I am not satisfied that it would always yield negative results.

Retinitis Pigmentosa.—In the treatment of this most troublesome disease medicinal measures have been of little avail, and we are forced to tell the unfortunate sufferers that they must reconcile themselves to the inevitable. The only possible escape from this disheartening prospect, if one there be, is in the use of electricity. Several cases have been placed on record, by trustworthy observers, in which either an improvement in the condition or an arrest of the disease has been brought about by the use of galvanism, and the results of these experiments commend themselves to all those interested in ophthalmological progress.

In 1873 Dor reported that he had obtained an improvement in central vision and an increase in the visual field by the use of galvanism, and some time after Mr. Gunn published the results of his experiments in the same disease, likewise reporting most satisfactory results. Mr. Gunn applied the current with the anode over the closed lids of one eye and the cathode on the opposite eye, or temple; the current was gradually increased from 5 to 7 cells, until a distinct sensation of a flash of light was experienced by the patient on making or breaking the circuit. The anode was then moved about on the nape of the neck, mastoid and supra-orbital regions, to determine what point gave the most marked light-sensations to the patient. When this point was determined, the cathode was kept there for half a minute or so, removed, and re-applied. It was next applied to a corresponding point on the opposite side of the head, and then to the closed eyelid of the same side; in each position it was applied for a few seconds; afterward both poles were removed and the cathode applied where the anode had been, the whole sitting lasting for from five to eight minutes.

In a paper presented to the American Ophthalmological Society, in 1886, Dr. Hasket Derby comments on these results of Dor and Gunn, and quotes personal letters from each, stating that they had continued the trials of the treatment. Dor says that he obtained "either a constant and progressive amelioration or, at least, a prevention of the natural increase of the disease." Mr. Gunn says, "I have followed only one case of those I then published, and there the improvement has been, or rather was, when last seen, permanent," although he is still disinclined to believe that the arrest will continue permanent.

Dr. Derby presented two cases of retinitis pigmentosa, on which the

current had been applied three times a week for three months. The sittings were for five minutes, with 6 to 8 Stöhrer cells. The electrodes were, as a rule, placed on the temples, but sometimes above and on the eye. The results were slight visual improvement and marked increase in the size of each visual field, as shown by the charts; he also mentioned a case treated by Dr. Standish, which Dr. Standish reported in detail at the next meeting of the society. It was of a woman, 33 years of age, who had noticed a failure of vision for three years; this had increased very rapidly in the three months previous to her first examination by Dr. Standish; her vision was, at that time, reduced to $\frac{12}{40}$ in the right and $\frac{12}{50}$ in the left. The night-blindness was so great that she could no longer go safely on the street at night alone. The ophthalmoscope showed a number of characteristic star-shaped spots of pigment in the periphery of the fundus of each eye. The field of vision did not extend over 20 degrees in any meridian in either eye. The patient was placed under treatment by the galvanic current, and no other treatment was employed. The sittings were of five minutes' duration, and were, as a rule, repeated every five days. The anode was placed on the closed lid, the cathode on the brow or temple; the current employed was not more than that given by 4 to 6 Stöhrer cells. The treatment was continued for fifteen months. The result was most surprising and gratifying. There was a constant improvement in vision up to the last three months, since which the vision has remained stationary. Upon one occasion, when the patient absented herself for a period of six weeks, after having been under treatment for four months, the vision and field were found to have fallen off slightly.

At the end of the treatment the vision was improved from $\frac{12}{40}$ to $\frac{12}{30}$ in the right and from $\frac{12}{50}$ to $\frac{12}{15}$ in the left, the field from 20 to 75 degrees right, 70 degrees left, horizontal diameters; 60 degrees right and 68 degrees left, vertical diameters. These measurements were made upon a perimeter, and the greatest care was exercised to make the different examinations under uniform conditions The ophthalmoscopic changes which took place while the patient was under observation were confined to a widening out of the prolongations of each patch of pigment so that they did not present so characteristic a picture as when first seen. No new pigment patches appeared. In the discussion of this case Dr. Derby introduced another, treated by Dr. T. E. Cheney, in which a marked visual improvement and an increase in the visual field were obtained, as well as a restoration of the field for red and green, which had been lost. The treatment in this case was similar to that employed by Dr. Standish, save that the applications were made more frequently.

This showing is certainly a very remarkable one, and, in view of the fact that no other method of treatment can show results which can compare with those just cited, and that in any event its employment cannot be attended by any ill effects, we are warranted in recommending it most

enthusiastically in any cases of retinitis pigmentosa that may apply to us for relief.

Diseases of the Optic Nerve.

Neuroretinitis.—There is much evidence in favor of the use of galvanism in inflammatory conditions of the intra-ocular extremity of the optic nerve. Benedikt, who believes papillitis to be a vasomotor disturbance, naturally advocates galvanization of the cervical sympathetic, and Driver, Erb, and others all report favorably on the use of galvanism in this condition. Erb believes it to be the most suitable object for galvanic treatment among all the anatomical diseases of the optic nerve; in view of the negative results of Bull quoted later on, we must accept this verdict with caution and give the question still further consideration.

The experiments of Rockwell, in determining the effects of galvanization of the sympathetic on the retinal circulation, should make us hesitate in denying that the results of treatment will never be more satisfactory than they have heretofore proved. When further study shall have given us a better understanding of what galvanization of the sympathetics will effect, and a more exact knowledge of the pathological conditions shall make us more certain of the indication for treatment, we may hope that electro-therapeutics may become a more efficient agent for relief. From a series of observations made with the co-operation of several most competent and conscientious observers skilled in the use of the ophthalmoscope, Dr. Rockwell arrived at the following conclusions as to the effect of galvanization of the cervical sympathetics on the retinal circulation :—

Rockwell's Experiments.—1. Galvanizing and faradizing the region of the cervical sympathetic have a marked influence over the retinal circulation. They may cause contraction of the arteries or dilatation of the veins. 2. The faradic current produces precisely the same effect on the retinal circulation as the galvanic, only more slowly. The physiological difference between the currents in this respect is, therefore, a difference of degree, and not of kind. 3. Mild currents and short applications caused contraction of the blood-vessels of the retina, where strong currents and long applications caused dilatation. Much seems to depend on the temperament and condition of the individual. What would cause contraction in one would in the other cause dilatation. These varying effects correspond with clinical experience. 4. When the patient on whom the experiment is made is in an excited or irritable condition from any cause, as from previous electrization, even a mild current will sometimes cause a dilatation at once, without any contraction. 5. The contraction which takes place is sometimes followed, a few minutes after the close of the *séance*, by dilatation which is greater than normal. 6. The dilatation which takes place is followed by contraction after the close of the *séance.*

Atrophy.—In the treatment of atrophy of the optic nerve by electricity, the observations of different investigators are most widely at variance. For example, Driver makes the following very hopeful statement: "The probability and possibility of improvement, or at least an inhibition of the process, may be assured when the disease has not yet reached the ultimate condition of total blindness, or long persistence in the bad state. But especially when there are spontaneous fluctuations of the visual field and acuity should galvanism be persevered in, and even if at first the improvement is scarcely perceptible." He advises the application of the constant current in three ways, viz.: 1. Through the head, either longitudinally with the anode on the nucha and the cathode on one frontal protuberance; or transversely, with the anode and cathode on each temple or both mastoid regions. 2. Galvanism of the sympathetic on one or both sides, with the anode on the nucha and the cathode on the region of the upper cervical ganglion. 3. Locally on the eye, with the anode on the nucha and the cathode on the closed lids. He employs the positive pole always fixed and the negative pole movable, and a sitting should last from one to two minutes. He uses from 6 to 14 cells of a Stöhrer battery, and is careful to avoid inducing vertigo. In toxic amblyopia his results are less encouraging; he employs, in the treatment of diseases of the eye, only the constant current, the induced current never having yielded him any good results.

Mr. Marcus Gunn inclines favorably to a trial of galvanism in cases of atrophy, and has investigated the subject with great fairness. As the result of a study of 18 cases he found that 6 were improved, 4 received doubtful benefit, and in 8 no good results were obtained; 2 of the 6 cases at first improved subsequently returned as bad as ever, and were not a second time favorably affected by treatment.

Erb reports favorably on the use of galvanism in optic atrophy, but has obtained less encouraging results in primary atrophy than in that following inflammatory processes. He believes, however, that in the former cases the treatment is still of some avail. It is important to begin the application of galvanism very early in the disease, for it is only then that there is any hope of retaining the vision. The result, as shown by visual improvement, is more marked than in the ophthalmoscopic appearance. In cases of atrophy with no assignable cause the results are a little more favorable. Erb quotes Dor as having obtained very favorable results in a large number of cases. He believes that a considerable improvement may be obtained in at least 40 to 50 per cent. of cases.

Erb's method of treatment for affections of the nerve is, "first, transverse passage of the current through the temples in order to affect the optic nerve in the orbit with the reversals of the current, and then longitudinal passage from the nape to the closed lids. When neuritis predominates, the anode principally must be placed on the eye and the cathode only temporarily stabile; but when atrophy has come on, the

cathode chiefly on the eye after the anode has acted for a little stabile, and to a small degree labile. Finally you must try galvanism of the sympathetic after the usual method."

Leber recommends the constant current in uncomplicated cases of atrophy, as likely to produce some improvement, or at least an arrest of the process. Soelberg Wells advises the use of the current with the anode on the nape of the neck, the cathode on the closed lids; daily sittings with 4 to 14 cells. Dr. Charles Stedman Bull, a very accurate and careful observer, has given the subject much consideration, and as a result of his observations says: "Up to within the last two years the reporter has employed the galvanic current in every case of optic-nerve lesion that occurred in his private practice, and in many cases in hospital practice. His results were so negative, and in many cases so unfavorable, that for two years he has entirely given up galvanism as a method of treatment in these diseases. From his own experience and that of others, as found in ophthalmological literature, he thinks he is justified in drawing the following conclusions: 1. In optic neuritis from whatever cause, and in papillitis or choked disc from intra-cranial tumors, galvanism, whether direct through the closed lids and eyeball or indirect through the cervical sympathetic, has no real value and should be abandoned. 2. In optic neuritis due to heredity or congenital tendency, galvanization of the sympathetic nerve in the neck is of no value. 3. In simple, uncomplicated atrophy of the optic nerve, the use of the constant current cannot be said to promise either positive improvement or an arrest of the degenerative process. In most of the cases in which an improvement of vision has been noted it proved to be merely temporary; and the same may be said of the apparent retardation of the degenerative process. 4. In cases of injury to the optic nerve, galvanism has not proved of the slightest permanent value. 5. In traumatic anæsthesia of the optic nerve and retina, uncomplicated by any laceration of nerve-tissue or rupture of nerve-fibres, galvanism carefully and persistently applied has been known to produce a rapid and permanent improvement of vision, when applied directly to the closed lids and the current passed through the eyeball."

The conclusions of Bull are certainly entitled to great weight, and are far from encouraging. My personal experience has not been sufficient to entitle me to an opinion in this matter; some few cases have under treatment apparently improved, but in the majority of instances the results were negative. The desperate nature of cases of optic atrophy justifies us in employing any treatment that gives the slightest promise of improvement, and the considerable number of reported cases in which some degree of success has been obtained warrant us in giving this treatment still further trial.

Diseases of the Ocular Muscles.

Paralysis.—There is the widest divergence of opinion as to the use of electricity in the treatment of paralytic affections of the motor apparatus of the eye, both as to its utility and as to the best method of its employment. Ophthalmic surgeons are not, as a rule, enthusiastic in its advocacy; yet I think the majority of them are in the habit of employing it as routine treatment in these affections. The views of many are well expressed by Mr. Barry, who says: "Electrical stimulation of the weakened muscle, either by constant or the induced current, is recommended by many, and is occasionally of use. . . . There is a great tendency for the paralysis of the ocular muscles to disappear more or less suddenly, and after having persisted for a longer or shorter period. Some cases, indeed, only last a few days; they are, consequently, well suited to confirm the faith which many place in electro-therapeutics, which, in point of fact, is about as successful in ocular as in other paralyses." He recommends the direct stimulation of the paralyzed muscle, either with the constant or induced current. In this point, again, we find little agreement among those reporting favorably on the use of electricity,—some believing that its action is from reflex stimulation, others through direct excitation to the muscle under treatment. The authority of Benedikt is the chief support for the theory of indirect excitation through the fifth nerve; he makes its sensitiveness the guide as to the strength to be employed, which should be sufficient to produce a slight sensation. Weak currents and short sittings are advocated. Althus indorses this theory of the action of galvanism, but finds faradism more effective. Erb, on the other hand, believes in direct stimulation by galvanism. He emphasizes the importance of first locating the lesion, as a basis for electrical treatment, and is not as hopeful as some of the good results to be anticipated in the presence of grave intra-cranial disease. He thinks that in most cases a study of the causes of the paralysis will incline us to the use of galvanism first of all to the point which has been fixed upon as the seat of the lesion. To bring the whole oculo-motor tract into the domain of the densest part of the current he places one electrode on the closed lids of the affected eye and the other on the opposite side of the neck and of the occiput; weak currents and short sittings are to be employed; he does not condemn the galvanization of the cervical sympathetics, which may be of occasional benefit, but places the chief reliance on the direct excitation of the paralyzed muscle by means of the cathode. To do this, place the anode on the nape of the neck, and pass the cathode backward and forward over the closed lids near to the surface of the muscles which are chiefly to be influenced, and also let the cathode act stabile for some time on the same spot. Thus, for example, for the internal rectus on the inner side, for the superior oblique inward and upward, etc. The

strength of the current should be sufficient to cause distinct burning of the lids and lively contraction of the frontal muscles when the temple is treated. He gives about half a minute to each muscle, and condemns overstimulation, advising testing the immediate effect and stopping when improvement is no longer obtained. The result of electrical treatment he considers favorable in cases suitable for it. The immediate effect is often marked, but the improvement may not be permanent, and many cases are very tedious. Faradism is much commended by many, and is of undoubted benefit in some cases. The use of faradism applied by a small electrode or the finger of the operator directly to the conjunctiva, over the insertion of the muscle, has long been known, and its use has been revived since the introduction of cocaine has rendered it less painful.

Many more authorities could be quoted, but the result would be only to multiply the mass of contradictory testimony. It would be most satisfactory could we determine positively how the current acts,—whether by the direct or reflex stimulation; but the practical results are not much affected by this question, and we must for the present be content with the conclusion that, on the whole, the use of galvanism is, in most cases, to be chiefly relied upon where the cause of the paralysis is such that improvement can be reasonably expected. I should incline to the use of the cathode to the closed lid, as near as may be to the insertion of the muscle to be treated, with a current of, say, 1 milliampère and sittings of from two to three minutes' duration. If, after a trial of a week or two, no satisfactory result be obtained, faradism should be tried, either on the lid or to the globe, with a mild current and short sittings.

Muscular Asthenopia.—The use of electricity in cases of muscular and accommodative asthenopia is recommended in a half-hearted way by most writers on diseases of the eye. " It is said to do good " seems to be the general verdict. It is quite a relief to find as good an authority as Dr. A. D. Rockwell state, as a result of his personal experience, that he believes " electro-therapeutics promises more for asthenopia with hyperæsthesia of the retina than any other disease of the eye." He advises a mild labile faradic current for five to ten minutes through the lid with the anode, either with a moist sponge or the hand of the operator, the cathode at the back of the neck or in the patient's hand. Stabile galvanism he believes to be also useful, and in cases associated with hysteria, dyspepsia, and general feebleness he advises general faradism. In his experience the tired, aching eye is relieved and the general tone after a time permanently improved. These observations of Rockwell coincide with my own experience. I have never used faradism, but I have seen most marked results follow the application of the constant current in cases of asthenopia from muscular weakness; that is, where the muscular equilibrium was not disturbed, but all the muscles lacked was the

power of enduring prolonged work; and in cases of insufficiency of the interni. In cases of asthenopia when, after the correction of all the visual and muscular defects, there is still an inability to use the eye as we could wish, I have had most happy results from galvanism. I use about 1 milliampère through the closed lids for five minutes, with frequent reversals of the current.

Vascular Tumors of the Orbit.

There are, perhaps, no more difficult and trying cases presented to the ophthalmic surgeon than those of vascular tumors of the orbit. They are usually rapidly progressive and demand active interference, because of the dangers of a rupture, either spontaneously or from some external violence; the absorption of the hard parts, especially in young subjects, from the constant pressure; and the danger to the eye itself, which is usually more or less imperiled by being crowded out of place by the intruding growth. It is alleged that such mild measures as influencing the general circulation by rest, low diet, and the like, conjoined with internal medication, have been effective in these cases; such happy results must, however, be very exceptional, and are not to be relied upon. Spontaneous cures may also occur, but in the great majority of cases active surgical interference is called for. Compression has been employed and is occasionally successful. Ligation of the vessels supplying the tumor may sometimes be feasible, but is often extremely difficult or impossible; ligation of the common carotid, which is perhaps the most promising method of treatment, is certainly a very grave operation, and should not be undertaken till safer methods have failed. Injection of various substances into the tumor to produce coagulation is much lauded, but it is very far from being a safe operation, and has been immediately followed by fatal results.

It is apparent that any safe method of treatment which at the same time offers a fair promise of success is a desideratum, and electrolysis seems to be such a method. It possesses the advantage of safety and leaves no disfiguring scar; the intensity of its action can be easily regulated, and is especially indicated in very young children, where other operative procedures are inexpedient. It may be employed in two methods,—first, by introducing one needle, placing the other pole with the surface electrode on the temple; second (bipolar), by introducing two needles, one connected with the anode, one with the cathode. The latter method is far preferable, if the tumor be of any considerable size. It is a wise precaution to use platinum needles; if steel needles are employed the anode cannot be deeply introduced, becomes readily corroded, and some hæmorrhage may follow its removal; pigmentations of the skin may occur from rust of the needles. Noyes advises that they be coated with collodion for a certain distance, to better protect the skin; he recommends that the anodal needle be first entered and allowed

to remain *in situ* while several punctures are made in its neighborhood with the cathode. If possible, it is better to use a needle prepared especially for this purpose, the shank of which is insulated, as shown in the accompanying cut. It has a bayonet tip (A) of platinum, with insulation (c c) of the shaft.

It is difficult beforehand to lay down any rules as to the strength of current to be employed or the duration of application; as in all other electrolytic processes, the operator is largely governed by the effect which is being produced. After the removal of the needle compression should be employed and the patient watched, lest bleeding should occur from the punctures. In many of these cases it is difficult to know the exact nature of the tumor which we are treating; our prognosis must therefore be very guarded.

Berry mentions a case of aneurism, the result of a penetrating wound of the orbit, which he considers a spurious aneurism of the ophthalmic artery, which Dr. Duncan successfully treated by electrolysis at the Edinburgh Royal Infirmary.

Dr. Charles Stedman Bull reported some time since, to the American Ophthalmological Society, a case of pulsating vascular tumor of the

orbit, eyelid, temple, and forehead, in which he employed electrolysis. The case is of sufficient interest to merit a rather detailed description. The patient was a female child 12 weeks old; a few days after birth two small white spots were noticed on the forehead, above the eye. When the child was about 3 weeks old the upper eyelid began to swell and the spots to grow gradually red. This continued till the time of the first observation,—*i.e.*, when the child was 12 weeks old,—when the child, perfectly healthy in every other respect, presented the following condition: "The swollen and purple eyelid projected almost directly forward in front of the plane of the orbit in a mass as large as the two closed fists of the child, so that in a profile view of the face it concealed the entire nose except the tip. The lower lid was entirely hidden from view by the overhanging upper lid, which was pushed downward much below the level of the lower orbital margin, and about on a plane with the juncture of the nasal cartilages and the naso-buccal furrow. The swelling extended over the entire upper lid, upon the bridge of the nose, and encroached upon the right side of the nose and nasal end of the right eyebrow. The child's forehead was rather prominent, and the swelling extended well above the frontal bones. The growth also filled the entire zygomatic fossa and nearly the entire temporal fossa, extending backward to the anterior edge of the concha. From the supra-ciliary region there extended upward two irregularly-shaped tongues, well toward the line

of the hairy scalp, which resembled strongly in appearance the ordinary vascular nævus. The skin over the whole region was tense, except at one point, the most prominent of all, and there the skin fluctuated on pressure and was evidently very thin; careful examination showed that the main swelling was in the subcutaneous tissue of the lid and eyebrow, and in the orbital tissue, while the skin itself was the seat of a pure nævus. The growth in the zygomatic and temporal fossæ, though yielding slightly to pressure, was firm and dense; but the swelling in the lids and orbit yielded markedly to pressure, and a few moments' compression with the finger directly backward toward the apex of the orbit sufficed to diminish the size of the tumor by from one-half to two-thirds." The eye, although displaced, was healthy. There was visible a slight pulsation on the apex of the growth, which was increased on pressure. "The thinning of the skin over the apex of the tumor and its easy indentation at this point convinced the writer that there was a cavity of some size in this region, which probably was entirely outside of the orbital cavity, and was filled with fluid, and that therefore the tumor was of a mixed nature, cavernous as well as telangiectatic. A vessel as large as a large goose-quill could be felt under the skin at the external angle of the lid, and another one somewhat less in size was felt running across the bridge of the nose." The pressure of the tumor had produced an absorption of the underlying bone in at least two places. This description of the case is sufficient to show that the tumor was of a variety in which it is commonly supposed that the action of electrolysis would be insufficient to produce a beneficial consolidation of its contents; at a consultation in this case Dr. Bull was alone in the belief that it was indicated, the consultants thinking that "owing to the extreme size of the tumor and also the probability that it was a mixed cavernous and telangiectatic growth, it should not be attempted until after the carotid artery had been tied." The patient was kept under observation for some time and the internal administration of ergot tried, the tumor increasing in size. An operation by electrolysis was attempted some six months after the child was first seen. The child was etherized, the needle connected with the cathode introduced at the external end of the orbit, and the anode with a sponge-disc placed over the swelling in the temporal fossa; 2 Stöhrer cells were at first employed, which were gradually increased to 16. The current was passed, in all, six minutes; a small nodule of condensation was felt at the cathode; no reaction. On the third day after, the treatment was repeated; the anode was at this time moved slowly all over the nasal half of the tumor. This session lasted twelve minutes; marked nodule of condensation at cathode, and the needle was removed with some difficulty. Six days later a third session was held; needles were used at both poles. The cathode was introduced on the nasal side, the anode on the temporal side. The distance between the points was about half an inch; marked condensation at the cathode, slighter harden-

ing at the anode; no perceptible diminution in the size of the tumor; current from 18 Spamer cells for twelve minutes. Fourth treatment four days later; two needles attached to anode and 22 cells were employed for fifteen minutes. The tumor blanched rapidly while the current was passing; much difficulty in removing cathode, which was followed by some fluid and much disintegrated blood; much reaction; temperature, $102\frac{1}{4}°$ F.; pulse, 108; vomiting, crying, and restlessness after five hours. There was extensive condensation about all three needle-holes, and a perceptible diminution in the size of the tumor. The unpleasant symptoms passed away on the following day, but the condensation increased; and in the space included between the points of entrance of the needles the tumor was hard, firm, and pulsation had ceased. This area was about a quarter of an inch in diameter. The hardening and condensation increased slowly as long as the child was under observation, but, unfortunately, it was removed from the hospital, against the express order of the surgeon. This case should make us very hopeful in undertaking the use of electrolysis in similar cases, for we have every reason to believe that the outcome of the case would have been most satisfactory.

I have now under treatment a somewhat similar case, in which a favorable outcome seems highly probable. The tumor was rapidly increasing in size before treatment was instituted, and its progress was arrested and a slight diminution followed the first application of a current of 7 milliampères for three minutes; the needles attached to both poles. Several applications were then made with a needle attached to the cathode, anode externally over the tumor. No good result was apparent after these applications. Treatment was then resumed with both needles, and after several applications a decided diminution in the size of the tumor and a marked decrease in density were apparent. A current of 10 milliampères for five minutes has been employed in the last few applications.

DISEASES OF THE BRAIN.

By C. EUGENE RIGGS, A.M., M.D.,

ST. PAUL, MINN.

Electricity in Brain Disease.

While electricity may be prescribed theoretically in perverted functioning of the brain arising from nutritive and circulatory disturbances, the indications for its use are, in general, empirical. The lack of other resources and the good results which have been secured in some cases form the strongest indication for its use. In many instances, of course, the nature of the trouble forbids the hope of more than a passing amelioration, but even this it is worth while to bring about; in other cases, brilliant and unexpected results have followed its use.

The first point to be considered is the choice of the form of electricity to be used. Engelskjon has published a series of observations and deductions, in which he seeks to establish the theory of the opposite therapeutic action of the continuous and induced currents. According to him, in hemicrania and other neuroses of the central nervous system, and in those cases which would seem, by the clinical picture they present, to be indubitably related to anatomical lesions of the central organs, but whose course indicates rather a functional trouble, as well as in peripheral neuroses, if one current is shown to have a positive and beneficial therapeutic action, the other current will equally be found to have a negative or absolutely harmful therapeutic action; if one current relieves the symptoms, the other will aggravate them. He also claims that when a trial of the current does not immediately show which current is of positive therapeutic value in a given case, it may be ascertained by what he terms the electro-diagnostic examination of the visual field; the electrization of the encephalon, cord, ganglia, or skin exercises a powerful influence upon the functions of the retina, the current of positive therapeutic value increasing the visual field, and increasing, at least sometimes, the power of vision, while the current whose therapeutic action is negative or harmful narrows the field of vision. It is necessary that the current used should not be strong enough to produce cutaneous irritation, or the proposition does not hold good. In regard to this his critics have said that, while no doubt after electrization the field of vision is increased or diminished, the same phenomena have been observed apart from any electrization when perimetric researches have been frequently repeated. Also, most of the examinations of Engelskjon relate to the upper segment of the visual field, whereas the examination of the lower

segment would show more constant results, because of the involuntary modification of the limit of the upper sector by the eyelid; even if voluntary motion of the palpebral muscles is avoided, the current acts upon the innervation of these muscles. It is not necessary, then, to attribute the modification in question of the field of vision to the action which the current exercises on the medulla, nor is it safe to infer therefrom the specific value of the current. It is to be regretted that in this country no attempt has yet been made either to verify or disprove these theories.

As the vasomotor and catalytic actions of the current are chiefly desired in brain disease, it follows that galvanism will be more widely useful than any other form of electricity. The subject of the effect of static electricity in brain disease is generally neglected in the text-books, but Benedikt regards franklinic electricity in the form of the static breeze applied to the head as a powerful modifier of the intra-cranial circulation. As will be observed from the following pages, I have frequently found, in my personal experience, that the combined use of galvanic and static electricity produces better results than galvanism alone.

The desired effect upon the brain is in some cases best obtained by direct galvanization of the head and neck; in others, galvanization of the spine affecting the brain by reflex action has proved more effective. Stimulation of the integument has also been shown to affect the brain reflexly, and the electrical treatment of those peripheral tracts in which the symptoms manifest themselves is also of value.

Galvanism may be applied directly to the brain, either in the form of the continuous current or of voltaic alternatives. I wish to say a special word in behalf of this latter application, which is not very usual, but which I have found very effective in the limited number of cases in which its use was indicated; these have often been cases in which no other form of electricity was of service. The indication for the use of voltaic alternatives in nutritional and organic cerebral disease is pallor of the optic disc. It is my uniform custom, before applying voltaic alternatives, to make an examination of the background of the eye. Where there is any indication of a congested optic disc they are absolutely contra-indicated. The current should be from 2 to 5 milliampères, passed from three to five minutes longitudinally through the brain, one electrode being placed upon the forehead, the other upon the nape of the neck. The eyes should be examined, from time to time, to afford indications for or against its continued use. The effect of voltaic alternatives is, of course, much more powerful than that of simple interruptions of the current; but I have never yet seen a single case of vertigo caused by their use, although a single interruption of the current so frequently produces it. In the ordinary instrument, the only way of alternating the currents is by hand, by turning the key, which is not only tiresome, but also undesirable, as the frequent use of the commutator in this manner renders the battery unreliable for careful diagnostic work. Also,

in using the hand, the precision of the "make and break" will necessarily vary a little; consequently there will not result the same smoothness of current as though the action were automatic, and the danger of unpleasant effects upon the patient is greater. To remedy this defect I have had constructed for me, by the Waite & Bartlett Manufacturing Company, an automatic commutator, which has proved very satisfactory.

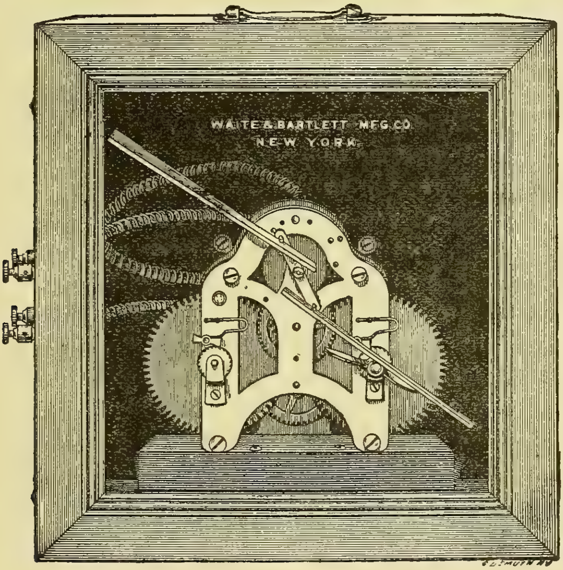

FIG. 1.

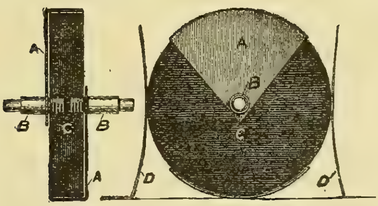

FIG. 2.

NEW AUTOMATIC POLE-CHANGER FOR USE IN THE APPLICATION OF VOLTAIC ALTERNATIVES.

It has three sets of fans for regulating the speed. With the large fan the polarity is changed 150 times a minute; with the medium, 200; with the small, 250. *C* is a hard-rubber wheel. *B* and *B'* form the shaft, but do not touch each other. *A* and *A'* are pieces of brass bent like *D*; they are fastened on opposite sides of the wheel, *C*, and connected to the shafts. *D* and *D'* represent two brass springs which press on the wheel, *C*, so that as *C* revolves the brass pieces *A* and *A'* touch the springs *D* and *D'* at the same time.

The galvanic current stabile may be applied to the brain longitudinally, one electrode on the forehead and one on the nape of the neck; transversely, one electrode over each mastoid region; obliquely, or "localized," one electrode over the convolution supposed to be the seat of the lesion, the other on the opposite side of the neck, in such manner

as to bring the seat of the lesion in a direct line between the electrodes. The so-called "galvanization of the sympathetic"—a term to which de Watteville objects, substituting therefor "subaural galvanization," on the ground that the position of the electrodes in question, while it has been shown to be practically useful, does not show the physiological effects which are ascribable to an excitation of the superior cervical sympathetic ganglion—consists in placing one electrode under the angle of the lower jaw, immediately adjacent to the hyoid bone, pressing it upward and backward, while the other electrode is placed over the fifth to seventh vertebræ.

The strength of current and the time of application vary, and, within certain limits, should be made to depend absolutely upon the sensitiveness of the individual to the current. As this varies greatly in different persons, a beginning should always be made with very weak currents, increasing in strength very cautiously, and giving all heed to the subjective symptoms of the patient. The dosage for the brain may be from 1 to 5 milliampères for two to five minutes, 3 milliampères being a medium dose. For the spine the dosage may run from 3 to 20 milliampères or even higher, 10 milliampères being a medium dose. In applying the electrode labile along the spine, care should be exercised, in the lower dorsal region, to keep it in close proximity to the spine, as, when using strong currents, if it is carried too much to the side, syncope may result. For application to the brain large, flexible electrodes should be used, and great care should be exercised in turning the current off and on gradually, to avoid shock.

The subjective symptoms and observed effects may also be relied upon in the much-discussed question of polarity and direction of the current. The theory regarding the differing effects produced by ascending and descending currents and the rules laid down for their use are now generally disregarded. While recorded facts demonstrate that there is sometimes a difference in the therapeutic action of the two poles, the claim of the advocates of the polar method of treatment to have established a physiological method has not been justified by the results. It is still customary, however, to apply the anode where a sedative effect is desired and the cathode where an excitant is needed, and this practice may still be followed in default of other indications. Such indications, however, especially in the galvanization of the brain, may be afforded by the subjective symptoms of the patients. De Watteville avers that if there is a therapeutic difference in the action of the poles it must be established and defined empirically in each individual, as it rests upon some personal idiosyncrasy of the particular patient under treatment; and he states, as a general rule, that the best results are obtained by using both poles successively to each point of application, remembering only that the cathode has a greater local action, both chemical and stimulant.

As applied to longitudinal galvanization, the polar dictum directs the anode to the neck and cathode to the forehead, if it is desired to increase the flow of blood to the brain and to accelerate the circulation; the anode to the forehead and the cathode to the neck, if the flow of blood is to be diminished. As applied to transverse or localized galvanization of the brain, it directs the anode to be applied to the diseased side, if the circulation of the brain is to be increased; if it is to be diminished, the cathode. If this basis of treatment is adopted, it should be remembered that it is purely theoretic; and whenever the expected results do not follow the use of the theoretically-indicated pole, the contrary pole should be tried.

In the treatment of diseases of the brain, while the principle of applying the current as far as possible to the seat of the disease should be carried out, the value of reflex action upon the brain and of treatment directed toward the symptoms should not be overlooked. Central galvanization, spinal galvanization, general faradization, static insulation, and general franklinization may be very valuable adjuncts to local application. The galvano-faradic current applied to the spine I have sometimes found effective as a general tonic where all other forms of electricity have failed to produce any result. Use 5 to 10 milliampères of galvanism, with the faradic current of such strength as the patient finds agreeable. Those who are very susceptible to the influence of electricity will tolerate best a weak galvanic current with a stronger faradic. In these cases the combination will be found to produce better results than the faradic used singly, because of the physiological effects of the galvano-faradic current.

In relation to the kind of treatment best employed in connection with galvanization of the brain, a theory advanced by Engelskjon is interesting. Its practical value I have not tested. He says, "A pathological state of the spinal ganglions may, by reflex action upon the cord, be the occasion of the development of morbid spinal symptoms. Also an affection of the medulla can, by reflex action upon the brain, determine cerebral symptoms. The reflex process is always ascending. Almost always the organ secondarily affected should be treated by a different kind of current from that primarily affected. Every cerebral neurasthenia, every headache, every vertigo and dizziness which is accompanied with spinal symptoms, indicates that there is reflex action upon the medulla, whence the utility of applying to the brain one sort of electricity and to the cord the other sort. There is the same reflex action of the cauda equina with relation to the medullary axis." It is a somewhat singular fact that, while the symptoms of what Althaus terms "galvanic saturation"—the "electric neurosis" of some other writers—are frequently observed in neurasthenic conditions as the result of prolonged treatment by electricity, I have never yet seen them following treatment of brain-lesions or of the psychoses.

It is, of course, understood that, in all the diseases treated of in this

section, the usual therapeutic endeavor indicated in the different conditions should be carried on in connection with electrization, although in many of them I regard electricity not as adjuvant, but as the chief agent.

Electricity in the Treatment of the Psychoses.

It is now quite generally conceded that electrical treatment has a definite curative value in cases where mental disorders are due to functional disturbances and circulatory derangements. Its use may also be successful in the reduction of symptoms where mental disease is the expression of deep-seated organic changes in the cerebrum. There are many reported cases in which the use of electricity in mental derangements has cured insomnia, caused the disappearance of painful intra- and extra- cephalic sensations, congestion of the face, epigastric oppression, false perceptions of all the senses, notably of touch and hearing, and has also been successful in reducing the symptoms of disordered motor action, such as chorea, ptyalism, and stuporous manifestations.

Erb considers that the catalytic action of the galvanic current is of the most value in the treatment of insanity, and next in importance are its vasomotor effects. It is well established that circulatory derangements are the controlling factors in many forms of mental trouble. Dr. Williams, discussing the relation of encephalic circulation to mind, suggests that many mental processes otherwise obscure find an elucidation in the explanation of the blood-supply, some of the most conspicuous phenomena of mind being associated with arterio-serous, arterio-venous, and interarterial fluctuations. Under the head of arterio-serous fluctuation comes the excessive hyperæmia of the cortex, found in some abnormal conditions, and produced by a general dilatation of the arterioles dependent upon a failure of co-ordination in the centres of vaso-constriction; the mental concomitant is a confused and meaningless rush of ideas: the normal mind is gone. On the other hand, the mental concomitants of great arterio-venous oscillations are depression and hebetude, amounting in extreme cases to melancholia, since "turgescence of the veins of the brain is a practical withdrawal of so much blood from efficient circulation," and from the feeble current results a loss of the normal tonus of the vessels, insufficient oxygenation, and inefficient energizing of the brain.

It will be seen that just in so far as we have in electricity an efficient means of vasomotor regulation, and so of effecting a true physiological tonus of the blood-vessels, we have in it a proper therapeutic agent for cases of mental alienation dependent upon circulatory derangements. Arndt, who has studied the use of electro-therapeutics in the treatment of the insane more thoroughly than any other writer upon the subject, in his latest summing-up of the subject (Tuke's "Dictionary of Psychological Medicine," page 428), lays down the following principles:—

Electricity, if used carefully and perseveringly, is an invaluable

remedy in the hands of the alienist. "It is a stimulant, and the biological principle that weak stimulants excite vital action, medium ones promote it, strong ones hinder it, and very strong ones extinguish it finds here complete confirmation." As the insane are usually weak or even decrepit, it follows that the weak currents must generally be applied. Arndt believes that the length of application should be inversely proportional to the current-strength, thinking that good results can be expected only from long-continued applications. He insists strongly upon this point, on which he differs with the majority of medical men, averring that non-observation of this rule is the principal reason why there have been in general so few good results in the use of electricity in insanity. He sometimes galvanizes patients for twenty or even thirty minutes. Where it is desired to produce a change in nutrition, the constant current should be used. "In the condition in which the usual treatment consists in rest, strengthening diet, and tonics, electrization of the whole body—so-called general galvanization—is indicated. The anode is placed on the back of the head, the cathode on the extremities, in the form of a foot-bath, metal plates, or sponges. The current descends from the head to the feet. . . . In this manner of electrization the anode has usually the form of a disc, or is double, so as to be applied simultaneously on both sides of the head or neck." If at the same time it is desired to excite, the more or less often interrupted galvanic current is used; and if strong excitation is desired in the first place, the induced current. If the sedative effects of electricity are desired, use the galvanic current, applying the anode. "If we want to excite generally, and if the stimulation at first must be slight only, we place the anode at the feet, and move the single or double cathode gradually up and down over the whole surface of the body, and frequently interrupt the current or change its direction. If the excitation has to be stronger, and has chiefly to combat a more or less marked cutaneous anæsthesia or muscular atony,—both conditions found in paresis and stupor,—we apply faradization. We brush the whole surface of the body gradually with both electrodes in the form of wet sponges or of the faradic brush."

As faradization is believed to act as a powerful stimulant upon diseased nervous centres, it is contra-indicated where the symptoms point to increased excitability. On the other hand, it is indicated in cases of simple atony of the brain, paralysis, and decreased excitability of the brain. It should be remembered, however, that some conditions of excitability are due to paralysis, and some forms of stupor may be caused by spasm and not by depression. In the majority of mental diseases the conditions are those of overexcitability. According to Arndt, "The conditions of mental depression, melancholia, even a kind of stupor,—stupor caused by inhibition, or stupor spasticus, as we have named it,—are nothing but the expression of such conditions of excitability." This, however, is not the commonly-received view. The venous engorge-

ments in the extremities found in cases of paretic stupor improve when treated by interrupted or labile galvanic currents and by faradization, while stabile galvanic currents are useful in the obstinate costiveness found in melancholiacs.

Little has been published regarding the use of static electricity in mental disease, but I habitually make use of it in combination with simple galvanic currents, as I believe its tonic properties are equal to those of any other form of electricity; and general franklinization fulfills all the requirements of a faradic current, with the exception, in my observation, that its stimulant properties are less marked. Its use also avoids the disrobing, to which many patients object. As a sedative, its influence is unquestioned, although, as mentioned below, in rare cases it has been found to irritate. In the Dordrecht Asylum Report for 1888 it is stated that electricity has been tried among the patients with varying results. As regards franklinization, "while various patients experience an agreeable feeling of relief and improvement when under a positive current, the reversion of such induces a feeling of oppression and aggravation of symptoms. In one case the galvanic current, both anode and cathode, determined a return of aural hallucinations, which had been absent for some time." In my own practice I have used chiefly static insulation and gentle galvanic currents applied to the cord, medulla, and brain, with, in some cases, galvano-faradization. The results have been excellent. In melancholia especially I have found electricity a most valuable remedial agent. Again and again I have seen the hallucinations and fixed ideas, so well marked in this disorder, disappear under its use, and it is the general testimony of the profession that this psychosis is especially amenable to electrical treatment. Alex. Robertson (*Journal of Mental Science*, April, 1884) reports a case of melancholia, with hallucinations of hearing and suicidal impulses, of seven years' standing, which he treated with galvanism, commencing with a gentle current applied for seven minutes, increasing the strength as the patient was able to endure it, but, with the strongest current used, decreasing the time of application to five minutes. At the end of five months the patient was discharged completely cured, and a year after she left the asylum the cure was still maintained. In this instance the positive pole was applied to the superior cervical ganglion of the great sympathetic on each side, the negative pole being moved slowly on the same side, from the region over the eyebrow to the occiput and up to the median line of the skull. Tigges reports five cases of melancholia in which, under the action of the continuous current, the abnormal sensations, the paretic troubles, and tremors entirely disappeared, and the patients were cured in, respectively, eleven, fourteen, eighteen, nineteen, and thirty days; also, three cases of melancholic stupor were cured under the influence of electricity. In my own practice, the case of melancholia of longest standing cured was one in which the disease had been present for two

years. This case was cured in about ten weeks. A case in which the only symptoms were mental pain and fixed ideas was cured in a week, the condition being seen to give way from the very first application of the current. The most unusual case that has come under my observation was one in which the mental pain was very great, and almost constant hallucinations of sight, hearing, and smell were present. This patient heard the voice of the devil, smelt the brimstone, and saw the flames. She also suffered from attacks of præcordial fright. Under static insulation and galvanization of the medulla and spine she made a good recovery in about two months.

I use in melancholia static insulation combined with galvanization of the medulla, spine, and brain, or general galvanization. Static electricity in melancholia, however, must be used very carefully, and the application in no case relegated to the hands of an assistant until the effect upon the patient has become evident, as, in rare cases, I have known it to increase all the symptoms. As to the dosage of galvanism, I have always found that melancholiacs could take a medium current,—say, 10 milliampères, and often 15. I have treated several cases of the developmental insanities and of morbid mental irritability due to the stress of growth with electricity, and found it very effective, the nutritive condition improving much more rapidly than under the usual treatment without electricity. Nearly all the patients made a good recovery. I would like to call attention to, and stimulate investigation in, this class of cases as to the usefulness of the galvano-faradic current in conditions which have shown themselves obstinate under simple galvanism. In the case of a young man, at present under my care, the use of static insulation and spinal galvanization for six weeks produced no effect whatever. Still continuing the static, I substituted the galvano-faradic current for simple galvanism, applying it to the medulla and spine. Improvement was almost immediately perceptible, and is still going on.

There can be no question of the value of electricity in insanity of the climacteric period. I have found beneficial currents of 3 milliampères to the brain and from 5 to 10 to the spinal cord. The insanity of this period usually takes the form of mania or melancholia, more frequently the latter, and the same principles underlie the treatment of this condition as of the original psychoses. In lactational insanity I have used insulation and galvanic currents. In one case in which I tried the galvano-faradic current following a course of galvanization the results were excellent. I believe this current, in virtue of its peculiar physiological properties, is well adapted to this class of cases.

In general paralysis of the insane, while, of course, the progress of the disease cannot be stopped, the symptoms may be alleviated. I have found the use of voltaic alternatives with spinal galvanization improves the nutritive condition of the patient, lessens the extreme explosiveness of temper, allays the mental excitement, and often renders the patient

quiet, harmless, and easy to take care of. Naturally, my views as to the value of electricity in these cases are not based upon the subjective sensations of the patient, these being characteristically unreliable. In one case of general paralysis which I treated with voltaic alternatives, the wife of the patient told me that his memory improved, the improvement not being connected with any of the general remissions by which the disease is marked. His field of vision also was enlarged and sight improved.

The result of persistent treatment in paranoia is disappointing. I have found no record of any improvement in paranoiacs under treatment. I treated one paranoiac for a year without the slightest alleviation in his condition, and this notwithstanding the fact that he came under my care at the time when the characteristic delusion which was afterward to become systematized was just beginning to crystallize.

I have noticed in the aged an insane condition arising from nutritive enfeeblement, which is characterized by melancholia, sometimes associated with episodiacal attacks of frenzy, maniacal in character. This is often mistaken for the insanity which may arise from the degenerative changes of senescence, and is, therefore, permitted to drift on without treatment, being regarded as inevitable and incurable. This is an unfortunate misapprehension, for I have found this psychosis most amenable to treatment, and, next to a careful alimentation, electricity is the most valuable therapeutic agent. In these cases use both static and galvanic electricity. The latter should be applied to the head longitudinally, a very gentle current,—1 to 2 milliampères for one to two minutes, with 3 to 10 milliampères to the spine.

In primary dementia general faradization is indicated, and the faradic brush may be applied to the whole body. Some writers state that marked improvement has at times been noted under the use of the constant current. It is needless to say that in delirium grave (*mania gravis*) the use of electricity is absolutely contra-indicated.

Ladame reports that in psychic disorders having their origin in exhaustion and overwork he has found franklinization especially valuable, and he strongly advocates its use on the ground that, even where, as, of necessity, must often happen, it fails to bring about a cure, it has still, in his hands, proved most efficacious in giving much-needed relief and in fortifying the patient against the attacks and enabling him to endure them better.

Electricity has been but little used in any form of mania. Erb finds that it is contra-indicated in any condition of profound excitement, such as acute mania and in conditions of psychical hyperæsthesia. Tigges reports that, while not exercising any influence upon the development of the malady, electricity acts favorably upon the symptoms, especially the pathological sensations, and acts also, though only in a transient way, upon the agitations and state of the temper. Benedikt

reports the cure of a case of mania with grandiose delusions by the use of the electro-static breeze. The form of mania in which electricity can be used to the greatest advantage is probably the simple mania of Clouston. There is a line of cases familiar to every alienist, characterized by marked psychical exaltation, approximating mania, yet falling short of it, in the treatment of which electricity will be found very valuable. As an instance in point, I may cite the case of a patient, a woman of high intellectual development and social gifts, who sought advice for supposed nervous prostration. She had been more or less an invalid for years, had given up society because it was too great a burden, yet lived continually in a state of marked mental exaltation. She exaggerated small incidents into important events, fancied that people were exerting baneful mesmeric influence over her friends, and that she herself was conscious of such influences from people with whom she came in contact, and believed that she acted under the direct guidance of the Divine Spirit; in the night she would often wake with an inspiration to write, and would arise and write messages from the other world to her friends, or thoughts of high import for herself, sometimes writing thus as fast as her hand could move for hours; she had the habit of opening books and marking passages at random, without looking at the page, and believed that every passage marked contained a message of divine purport to herself; she had an idea that she must leave her home and child and devote herself to the elevation of women, to teach them how to live, and bring them into the same exalted condition in which she rejoiced. These erratic ideas, however, were not of sufficient strength and tenacity to justify their classification as fixed delusions, and, while the flow of her ideas was very rapid and the condition of *bien être* very marked, she was mentally coherent. There was unquestionably a hysteroid element present at times, as she sometimes thought herself dying, and imagined that it was only by the utmost exertion of will on her part that she retained life in her body. The treatment prescribed was the static breeze, with spinal galvanism, constructives, nutritious diet, and rest. She grew better from the very first, and when she left my care her general condition and nervous tone had improved immensely; her chimerical ideas had lost their hold upon her, and she had come down to the plane of actual life.

Under the head of hypochondriasis have been classed a wide range of disorders, varying from a slight oversensitiveness and tendency to exaggerate ill feelings to insanity with delusions and suicidal impulses. There is much difference of opinion among writers as to whether it should be classed as an insanity or not. It is most often found, however, among those having a neurotic heredity. Wendel defines it as a functional disease of the brain, whose chief symptom is an anxiety regarding the patient's own bodily condition. Savage says that it may be a functional disorder, and nothing more; that it may be a symptom of organic

disease of some bodily organ; or it may be a symptom of disease of the brain, such as general paralysis; and defines it as the interpretation in a special, exaggerated, or unnatural and unreasonable way of certain bodily sensations. Where hypochondriasis is dependent upon some actual bodily disorder, the treatment, of course, depends upon that of the existing trouble; but where it is functional we may use the same treatment as in melancholia, into which psychosis hypochondriasis imperceptibly melts. In the young and in cases of recent development the prognosis may be favorable, but very often the disorder will be found most obstinate and will tax to the utmost the physician's resources. I have found it less amenable to electro-therapeutic treatment than melancholia. General franklinization and the faradic brush are sometimes of value, the object in their use being to change the character of the patient's sensations, as well as to help in stimulating the nutritive condition. I have seen marked improvement follow their use in some cases. While I do not for a moment underestimate the stimulative, tonic, and sedative properties of electricity, it is also true that in such disorders as hypochondriasis the suggestive influence is very pronounced. In this class of cases I am always careful to employ static electricity in combination with whatever other treatment may be chosen, because of its marked "suggestive" properties.

Cerebral Anæmia and Hyperæmia.

Electricity may be used to advantage in the brain conditions which are usually diagnosed as cerebral anæmia and hyperæmia. It was Lowenfeld's theory, regarding the action of galvanism on the brain, that the positive pole at the forehead and the negative at the neck occasion a contraction of the arteries of the pia mater; the anode at the neck and the cathode at the forehead, a dilatation of the arteries; in transverse galvanization the dilatation of the vessels occurs on the side of the anode, and the contraction at the side of the cathode. The correctness of this view has been denied by other authorities, but empirically in longitudinal conduction of galvanism through the brain it is still customary to put the anode on the forehead in hyperæmia and the cathode in anæmia. The intra-cranial circulation is also affected by the reflex action from the skin induced by means of the faradic brush. De Watteville recommends the use of cutaneous faradization of the neck, trunk, and arms with moderately-strong currents, in addition to longitudinal galvanization, in hyperæmia. Hammond uses galvanization of the sympathetic and transverse galvanization. In any case, weak stabile currents should be used, not continued for more than three minutes. They may be given daily.

In cerebral anæmia de Watteville recommends very weak galvanic currents to the head, following the unipolar method, one electrode resting on a distant part of the body, the other successively brought in contact with the frontal, occipital, and parietal regions, so as to act directly

upon the whole cortical substance; or the electrodes may be applied in the longitudinal, oblique, transverse, and subaural positions. The polarity of the electrodes may be determined empirically for individual cases. General faradization, including especially the frontal and occipital regions, and galvano-faradization of the abdomen wherever there is visceral torpidity, may be used. Hammond recommends very weak currents, only passing them for a few seconds.

In the use of a remedial agent whose possibilities have not been wholly explored, not only does clinical experience frequently contradict theory, but one man's clinical experience may differ from another's. All the authorities whom I have examined recommend only the stabile current, taking great care that there shall be no interruptions. In the conditions of malnutrition usually associated with cerebral anæmia I have derived unquestioned benefit in several cases from the use of voltaic alternatives.

In a series of cases which I have been studying with Dr. J. W. Chamberlin, of St. Paul, it has been demonstrated unquestionably that their use increases the amount of blood in the head, an examination of the eye before treatment showing the eye-disc pale, while an examination immediately after the treatment has revealed a decided flush. Along with the use of voltaic alternatives it has been my custom to employ galvano-faradization of the spine, using the voltaic alternatives one day and the galvano-faradic current the next. I apply the voltaic alternatives, using a current of 2 to 5 milliampères longitudinally to the brain. It may be well to emphasize again here the absolute necessity of examination of the eye before their use, as they are always contra-indicated, and may do great harm if used where there is any irritability or congestion of the retina.

Cerebral Neurasthenia.

The treatment usually recommended for cerebral neurasthenia consists of very weak stabile currents passed longitudinally, transversely, and obliquely through the head. Or one electrode may be placed upon the vertex and anterior part of the head, the other upon the feet. Subaural galvanization and galvanization of the cord are often useful. The treatment must usually be long-continued, beginning with weak currents and long sittings. If the feeble currents are well tolerated, their intensity may be increased. Mild faradization is sometimes found useful in these cases. The faradic hand or general faradization may be used. Some cases are reported in which good results were secured by the faradic brush. I have secured the best results in my own practice by longitudinal galvanization combined with either static insulation and sparks or general franklinization. The treatment should usually be combined with galvanization of the spine.

Cerebral Hæmorrhage and Softening.

The results of the use of electricity in cerebral hæmorrhage have been variable; but, in view of the fact that there are so few therapeutic measures at the physician's command in such cases, a trial of electricity is almost always justifiable. It is hoped by its use to assist the process of reparation in the brain, promote the absorption of extravasated blood or serous effusion, aid in the establishment of collateral circulation, and overcome œdema and hyperæmia. Treatment should be deferred until the danger from cerebral fever, which frequently follows a hæmorrhage, is past. It may be begun three or four weeks after a stroke. In severe cases it should be deferred a little longer. A beginning should be made with weak currents, and the tolerance of the patient carefully tested before applying currents of the average strength. The treatment consists in galvanization of the injured portion of the brain, and galvanization or faradization of the injured muscles. Faradization of the brain is always contra-indicated, as weak currents can do no good, and strong currents are likely to do harm. The galvanic current may be passed transversely, longitudinally, or obliquely through the brain. The anode (Erb, Althaus) is usually applied to the side of the lesion, but, whatever arrangement is used, should unpleasant subjective sensations result from it, the reverse position of the poles may be tried. Softening of the brain, whether from thrombosis, embolism, or other causes, should be treated in the same manner as hæmorrhage. Galvanism is considered useful in the partial cerebral anæmia arising when a part of the cerebrum is suddenly deprived of blood by the embolic obstruction of a vessel, in restraining collateral hyperæmia and œdema. Bartholow holds that in these cases the application of transverse and longitudinal currents is proper soon after the effects of the shock have passed away.

Paralyses of Cerebral Origin.

The following paralyses may be of cerebral origin: Hemiplegias, diplegias, and paraplegias (the cerebral palsies of childhood), bulbar paralysis or glosso-labio-laryngeal paralysis, paralysis of the muscles of mastication, facial paralysis, paralysis of the hypoglossal nerve; also some ophthalmoplegias. In all these paralyses treatment should be directed first to the seat of the lesion, next to the paralyzed muscles, the effort being in the former application to promote vasomotor and trophic changes, and in the latter to affect favorably the nutrition of the muscles and preserve their physiological activity. By peripheral treatment also it is hoped to influence the brain reflexly, and to assist in the restoration of conduction to the motor-nerve tracts.

Hemiplegia is the most frequently observed of paralyses of cerebral origin. It is almost always due to cerebral hæmorrhage, softening, or embolism. The treatment applicable to the seat of the lesion in hemi-

plegia has already been discussed in the consideration of cerebral hæmorrhage and softening. The local treatment may consist in either galvanic or faradic applications. The hemiplegia will be entire and persistent if the hæmorrhage is situated in the knee and anterior third of the posterior division of the internal capsule, or if there be a large extravasation in the lenticular nucleus of the corpus striatum a similar result will obtain; but where the effusion of blood into that central ganglion is slight, absorption may take place in time. De Watteville's method of proceeding in hemiplegia is to apply a large electrode (anode) to the nape of the neck, and to place the other, also of large size, on the diseased side, and so as to include the seat of the lesion between the two, —*i.e.*, over the inferior fronto-parietal region. The hair should be well moistened. Then apply the cathode in the subaural position, the anode remaining on nape of neck. Next he applies the galvanic current labile for from five to ten minutes to the paralyzed muscles and nerve-trunks, the current being strong enough to produce slight muscular contractions. The cathode is applied to the arm, while the anode remains fixed upon the neck. Five to ten milliampères may be used. Althaus lays down the general principle that when the electro-muscular excitability is normal galvanization of the peripheral nerves is indicated; when it is diminished, faradization. It is often useful to combine the two, or use them in succession. Hammond states that he finds no other agent so valuable in hemiplegia as electricity, amendment usually following even in old cases in which there are tonic contractions.

When aphasia is present, it may be treated by applying one electrode over the region of the third frontal convolution and island of Reil, the other on the opposite side of the neck. Hammond recommends applying the galvanic or faradic current to the muscles concerned in articulation. When faradization is used, the method of applying it is the same,—labile with moistened electrodes. The treatment is much the same for all the cerebral paralyses, varying only with the seat of the lesion and the affected muscles. In chronic bulbar paralysis the galvanic current stabile may be passed transversely through the mastoid processes, varying the direction. In addition, longitudinal and oblique galvanization of the sympathetic and of the cervical cord may be used. Of necessity treatment to be effective must be very persistent in this condition. Forced movements of deglutition—from ten to twenty at each sitting—should be produced by applying the current repeatedly to the sides of the throat externally. Should there be paresis of the diaphragm, it demands faradization of the phrenic nerve. De Watteville uses labile galvanization of lips, tongue, and throat; with the anode fixed to the back of the neck, as high up as possible, apply the cathode to lips, tongue, soft palate, and pharynx, using one of the electrodes devised for the purpose. Let the current be as strong as the patient will take it for from three to five minutes. From a physiological stand-point I conceive the application

of voltaic alternatives will be found useful, stimulating as strongly as they do the nutrition of parts to which they are applied.

Paralysis of the muscles of mastication may be produced by bulbar or basilar affections, more rarely by disease of the pons, cortex, central ganglia, etc. The galvanic current may be applied to the brain transversely or obliquely, and the masseter and temporal muscles stimulated at motor points with the faradic current.

The most common form of facial paralysis, and also that most amenable to electrical treatment, is of purely peripheral origin, and so not to be treated here; but facial paralysis may also be caused by affections of the tract of the facial nerve in the brain (in apoplexy, cerebral hemiplegia), or by affections of the motor centres of this nerve in the cerebral cortex caused by abscesses, tumors, etc. In facial paralyses of cerebral origin the frontal portion of the facial nerve is usually unaffected, while the entire facial district is involved in peripheral paralysis. The electrical excitability is perfectly retained in the former case, the RD being present only in paralyses of peripheral origin, or in such bulbar paralyses as affect the fibres of the facial nerve below the nucleus, or affect the nucleus itself. In these cases it will be found that the muscles can be stimulated by the "static induced" current with much less pain to the patient than by the use of either galvanism or faradism. This is especially the case in treating children.

In the cerebral paralyses of children,—hemiplegias, paraplegias, and diplegias,—the prognosis depends upon the extent of the lesion, but is most often unfavorable. Electricity may be tried. There are a number of cases of cures recorded. Gray finds that if the use of the faradic current is begun early enough in infantile hemiplegia, it is sometimes very beneficial; he reports a case in which a good recovery was made. In paraplegias and diplegias, however, it has not proved of value in his hands.

Epilepsy.

According to the theories of Hughlings-Jackson, the nervous system is divided functionally or physiologically into three "levels" of sensory-motor centres, distinguished as lowest, middle, and highest. The lowest level corresponds practically with the "spinal system" of Marshall Hall, its sensory-motor centres being largely those of automatic, habitual, and reflex action; next comes the middle level, made up of centres whose action is subconscious; these are not, as yet, as well distinguished anatomically as functionally. They include, as to their motor part, the cortical motor area of Ferrier and the corpora striata; on the sensory side they probably include the greater part of the temporo-sphenoidal lobe, the gyrus fornicatus, and the inferior parietal lobule. The highest centres are situated in the anterior and occipital regions, the latter containing motor centres, and the hypothesis being that the former contain

sensory centres. All parts of the body are represented in the lowest level, re-represented with more complexity in the middle level, and re-re-represented in the highest level in combinations of still greater complexity. It is in connection with the action of these most complex, least automatic, most recently evolved centres of the last level that the phenomenon of consciousness arises, and thus, in addition to being the highest sensory-motor centres, they are the organ of mind.

Epilepsy, using the term in its broad, general sense, has been defined as a " paroxysmal discharging lesion " of this complex sensory-motor system. Such lesions arise from nutritive molecular disturbances which may be an inherited weakness, or they may arise from the stress of growth and development. They render that part of the nervous system in which they occur unstable, and the nerve-centres, which are regarded as accumulators in which nervous energy is stored, instead of giving off their energy only in response to due stimulus, liberate it irregularly and explosively. The lower centres, while equal to the independent performance of their own functions, are controlled in a general way by the higher, and this relation of subordination is such that the irregular discharge of energy of sufficient force in a higher centre may induce an excessive, explosive discharge of the lower centres, the intensity of the movements resulting varying with the extent and position of the lesion. This is epilepsy on its motor side. But as the higher centres are not only the seat of sensory-motor disturbance mechanism, but are also the " organ of mind " co-ordinate with whose activities the phenomenon of consciousness arises, we should expect lesions of these centres to produce not only sensory-motor, but also psychological phenomena, and this, in fact, is precisely what happens in epilepsy proper, the psychological phenomena varying from the slight loss of consciousness, which is the distinctive characteristic of epilepsy, to the most violent form of insanity.

Assuming the above hypothesis to be correct, it would seem that electricity, with its sedative and catalytic properties and its marked beneficial effect upon nutrition of the brain, as has been shown by its successful employment in psychical disorders dependent upon nutritive changes, was indicated as a therapeutic agent of marked value in the treatment of epilepsy. Theoretically, various authors acknowledge that it is so indicated. Says de Watteville : " The recent views concerning the motor functions of the cerebral cortex, and its implication in certain choreiform and epileptiform phenomena, lead one to think that, in those cases, at least, where the usual medication fails, cephalic galvanization should be tried."

In spite of the seemingly good theoretical basis, however, as a matter of fact electricity is used, and has been used, only to a very limited extent in the treatment of epilepsy. To this a phrase of de Watteville's cautious recommendation affords, perhaps, a clue. The " usual medication " is the bromide treatment, which has proved, on the whole, a safe

and moderately successful remedy in the hands of the careful practitioner, and there is a natural unwillingness to experiment with an uncertain, and possibly unsafe, remedy when a more familiar one is at hand. Certainly, electricity, if administered in the treatment of epilepsy, requires to be used with great caution. I have seen an epileptic attack precipitated by an interruption of the constant current.

Whatever the reason, while many writers express themselves favorably inclined toward electro-therapeutic measures, the literature upon the subject, both in books and journals, is extremely scanty. Erb has employed a stabile, very feeble current obliquely through the head, from the temporal region and upper part of the forehead on one side to the opposite side of the neck, with, if vasomotor symptoms are marked during the attack and also during the intervals, galvanization of the cervical sympathetic. The result of his experiments was such as to incline him favorably toward making careful trial of electrical treatment in epilepsy. He thinks general faradization may be employed for its indirect effects. Althaus finds faradization valueless, but cites several cases in which beneficial results have been brought about by the use of the continuous current when other modes of treatment had failed. He directs the electrodes to the mastoid processes, the cervical sympathetic, and those peripheral nerves in whose domain an aura is frequently, or occasionally, experienced. If points of pressure or galvanic painful points are present, they should also be treated. Bartholow sums up the facts which experiments have developed by saying that it is only adapted to essential epilepsy, and that it is admissible in cases characterized by anæmia and depression of the vital forces, and is not useful in conditions of plethora. The field seems a promising one for experiment in cases where experimentation is justifiable. The main points to be kept in mind are weak currents, application to the motor areas, and extreme caution.

Jacksonian epilepsy, which has its origin in some gross lesion of the brain, cannot, of course, be benefited by any ordinary application of the current. A suggestion recently made by an Italian physician, however, may possibly point the way to a time when electricity may be used in combination with cerebral surgery with brilliant results. The operation of removal by the knife of the diseased area of the cortex in Jacksonian epilepsy has already been performed successfully. There are disadvantages in the use of the knife, such as the danger of injury to the neighboring cortical region and the risk of severe hæmorrhage, and it is recommended that electrolysis be substituted. He would insert a platinum-tipped negative pole into the diseased brain-substance, the anode being placed upon the sternum. It is stated that a current of from 2 to 3 milliampères passed for a short time will bring about electrolysis of the diseased tissue. A successful operation of this nature has been reported in a case of meningo-encephalic gummosa.

Chorea.

I shall treat under this head only chorea proper,—the chorea of Sydenham,—as being the only motor disorder to which this title is applied in the treatment of which electricity is of value.

The pathology of chorea is a subject of dispute. The disease being a motor disorder proceeding from the brain, it is, of course, assumed that it depends directly upon some lesion of the cells of the motor area of the cortex, the psychical symptoms observed being further evidence of the involvement of the cortex; but whether the condition is organic as well as functional, and what is the nature of the lesion and the cause of it, are subjects of discussion.

While various cerebral changes—hyaline degeneration, arterial dilatation, cellular degeneration, hyperæmia, softening, increase of connective tissue, scleroses, etc.—have been found and described in fatal cases, it has usually been conceded that no one pathological alteration has been found so constantly associated with the disease as to warrant the inference of causation. Some authorities, however, regard hyperæmia, embolism, and softening as the cause of acute cases, and ascribe chronic ones to the presence of vascular irritation of a less degree. Others regard the changes in the brain-substance as either accidentally co-ordinate with or subsidiary to the functional disturbance of the nerve-elements, the intense overaction of these being regarded as affording a sufficient explanation of such morbid appearances as the vascular disturbances, increase of connective tissue, etc.

In an obscure affection which may get well without medication, such as chorea in the young, it is a little difficult to say with certainty of any remedy, *post hoc, propter hoc*. In my own experience, however, I have often noticed such brilliant results immediately following the use of statical electricity that I did not hesitate to ascribe the results obtained to the use of that agent. In one case, in which an attack of articular rheumatism was followed by acute chorea associated with great physical prostration and such an irritable stomach that internal medication had to be suspended, the most astonishing improvement took place from static insulation. That this did not occur simply as the result of giving nature a chance was proved by the fact that subsequent attacks were as readily amenable to treatment as the first one. I regard, however, a combination of the constant current and statical electricity as being the most beneficial. I recall one instance,—the case of a young lady who had suffered from chorea for five years, who was rapidly cured under this combination. The constant current should be applied longitudinally to the brain, 2 to 3 milliampères for two to three minutes; and to the spine, 10 milliampères five to seven minutes. In another case of chorea, the inco-ordination of movement in walking was so great that the child had to be assisted into the office. In this instance, although other thera-

peutic measures were combined with statical electricity, the improvement was so immediate as to preclude the idea that it was due chiefly to the medicinal measures.

Good results have been reported by various authorities following the use of static, galvanic, and faradic electricity. Althaus recommends and practices alternate galvanization and faradization of the limbs, together with gymnastic movements, and reports the recovery of most cases in a short time. Erb recommends that one electrode be placed on one side of the neck and the other on the opposite side of the head, so that the motor zone of the brain may lie between the electrodes, passing a feeble current for a minute and a half; or the unipolar method may be adopted, with the cathode in the hand and a bifurcated anode on both parietal regions. Galvanism of the sympathetic and cervical cord may be added.

Should there be painful points upon the spine and peripheral nerves they should be galvanized, applying the current stabile. In the greater number of reported cases of chorea treated by galvanism weak currents stabile have been used, but Moritz Meyer used successfully a strong interrupted current. Gray's method of using spinal galvanism as an adjunct in chorea is to apply a current of 3 to 5 milliampères every second day, placing one electrode on the occiput and the other on the lower dorsal vertebræ. It is only in the chorea of Sydenham that we may look for good results from treatment. What is termed by Ludwig Meyer the chronic chorea of adults is most obstinate, and has not been found to yield to electrical treatment. In those cases of chorea which are characterized by the extremely obstinate movements of the facial muscles which seem to resist all medicinal measures, faradization of the muscles may be tried. The current should be as strong as the patient can endure, and, by a little education and gentleness on the part of the operator, one of considerable strength will be tolerated. The muscles should be sufficiently contracted to tire them, this condition of fatigue seeming to afford an opportunity for the energizing of the muscular activities in a normal manner, and thus the habit may be overcome.

Paralysis Agitans.

According to the present views upon the subject, tremor is that modification of the normal muscular action which occurs when the successive simple contractions constituting the ordinary tetanic contraction follow one another too slowly, so that the beginnings of the relaxation become apparent (Mercier). All tremors not fibrillary in character are believed to be dependent upon the intermittent action of the gray matter of the central nervous system. Tremor is produced when, for any reason, the storage of force in the nerve-cell is diminished and its rhythmic discharge interfered with. Says Peterson: " The usual hemiplegic process of paralysis agitans, occasional inequality of the pupils,

the cessation of movement, as a rule, during sleep, and other arguments lead us to suppose a genesis of the vibratory contraction in the cerebral cortex."

All forms of tremor are difficult to deal with therapeutically. Electricity has been used chiefly in the tremor of paralysis agitans. It may afford a palliation of the disease, but usually not more. Erb is of the opinion that reported cases of recovery are due to erroneous diagnosis. The purpose of treatment is constructive. Static electricity, in the form of insulation and sparks, may be used. Sparks should be used over the larynx, if there is difficulty in speech. Longitudinal and oblique galvanization of the brain, galvanization of the cord, mild labile currents through the peripheral nerves and muscles, central galvanization, and general faradization may all be tried. Althaus thinks that where the affection is recent and the tremor circumscribed, affecting only a single limb, galvanization may be curative. Hammond, who uses electricity as an adjunct to hyoscyamine, employing longitudinal and transverse galvanization of the brain and galvanization of the sympathetic, reports one case of very decided improvement, amounting to a cure. Probably the most effective line of therapeutic endeavor that can be followed in this obstinate disorder is the combination of electricity with hydrobromate of hyoscine ($\frac{1}{100}$ grain from two to three times a day), and such tonics as iron, quinia, strychnia, and stimulants. As directed against the symptoms of paralysis agitans, electricity is of real value. In the more advanced stages of the disease the patients often suffer extremely from fatigue, prostration, and neuralgias. Opiates are useless, and are, indeed, contra-indicated, but the sedative qualities of the constant current often take their place with good effect.

Hemicrania.

There is much difference of opinion as to the true nature of hemicrania, or paroxysmal sick-headache, in which the pain is confined to one side of the head and the attacks are associated with sensory and oculo-pupillary phenomena. It has been variously held to be a neuralgia of the fifth nerve (this view, however, is seldom advocated any longer); to arise from derangement of the sympathetic, the two well-marked varieties of it being due, respectively, to dilatation and spasm of the cerebral arteries; a third theory is that the vasomotor disturbance is of secondary origin, the primary derangement being in the nerve-cells of the brain. This theory is that ably advocated by Liveing and supported by Gowers. Seguin regards it as a symptom of eye-strain.

Hemicrania sympathetico-tonica or angio-spastica is characterized by vascular contraction, the face being pale, the eye prominent, with dilated pupil and the temporal artery hard. Hemicrania angio-paralytica is characterized by vascular dilatation, the affected side of the face being red, hot, and turgid, the pupil contracted, the temporal artery beating

strongly, etc. For convenience and brevity I shall distinguish these, as I usually do for my classes, as the anæmic and hyperæmic varieties, the significance of the term being directed to the symptoms and not looking toward any theoretical explanation of the nature of the disease.

As the cause of the disease is not clearly ascertained, the treatment is empirical, and here also authorities differ as to the value of electricity as a therapeutic agent.

Gowers thinks it not often of value, and regards the methods of Holst, Frommhold, and Fieber as of doubtful service. Strümpell, while conceding that the application of electricity may do good as a general treatment, cautions us not to build too great hopes upon it. Althaus finds that hemicrania resists faradization, but yields to the persevering use of the constant current through the temples and mastoid processes. Galvanism is strongly advocated by Holst, who recommends the bi-polar method of application, using the anode in the anæmic variety in order to produce anelectrotonus, and the cathode in the hyperæmic variety to produce catelectrotonus in the nerve. This method of application, however, is more theoretical than practical, since, as de Watteville has shown, whichever electrode be placed over the nerve there is created in that nerve two virtual electrodes of opposite names, so that whichever pole is used the influence of the opposite pole is not eliminated. Holst applies one electrode at the inner edge of the sterno-cleido-mastoid muscle and the other to the palm of the hand, in the anæmic variety, closing the current suddenly and gradually stopping it after a passage of two to three minutes. In the hyperæmic variety he not only closes the current suddenly, but it is made to produce powerful excitations by means of repeated closures and openings or in some cases by reversals. This treatment has been recommended as giving relief during the attacks, and in some cases lengthening the interval between the attacks.

Frommhold and Fieber recommend highly the induced current. Frommhold uses the "primary induced" with one pole high up on the back of the neck in the median line, and the other over the superciliary arch. Fieber employs the "electric hand." Bartholow's treatment by galvanization consists in applications to the fifth nerve, the anode on the supra-orbital arch and the cathode on the mastoid, stabile applications being preferred. The simultaneous galvanization of the pneumogastric nerve and the sympathetic effected by placing one electrode on the epigastrium and the other behind the angle of the jaw is also recommended. Bartholow also states that he has found relief given during the hyperæmic attacks by a mild faradic current confined to the skin of the painful region, and a stronger current applied to the cervical and dorsal spine. Hammond finds galvanization of value between attacks, but does not regard it as ever the chief therapeutical agent.

In my own practice I have not found electricity of the slightest

value in affording relief during the course of any attack of either variety of hemicrania, and I can report no satisfactory results from the use of the faradic current. On the other hand, I have found electricity a most efficient agent in combating the disease itself. It is, perhaps, unnecessary to suggest that, before the treatment for hemicrania be begun, search should be made for eye-strain, and any eye-defect which may be found corrected, as well as any other possible cause of the trouble eliminated. I use static electricity in both varieties, but in the anæmic it acts in a particularly efficacious manner. In these cases it should be applied as electric breeze or spray to the head of the patient, by means of a pointed brass electrode, and should be made to play especially over the painful area and the region of the cervical sympathetic. I believe the spray and sparks act as an antispasmodic. The use of static electricity should be combined with longitudinal or central galvanization or subaural galvanization. As an adjuvant, trinitrine may be given in doses of $\frac{1}{150}$ to $\frac{1}{100}$ grain. Of course, the patient's diet should be carefully regulated.

In one case of the anæmic variety, the patient, a man, had suffered for years, and the trouble had grown steadily worse until the paroxysms were so severe and came so frequently, leaving him so prostrated after each one, that life did not seem worth living. Every remedy, except large hypodermatics of morphine, failed to afford relief. By the use of static electricity combined with longitudinal galvanization for three months, a practical recovery was secured, the attacks becoming slight and only recurring at long intervals, his general health being also greatly improved. In another case of the anæmic variety the best results were secured by the use of static and constructives. In the hyperæmic variety I use simple insulation for its tonic effects, as in all cases, the higher the nutritive condition of the patient, the less severe are the attacks likely to be, and combine with it galvanization, subaural, longitudinal, or central. As an adjuvant in the hyperæmic variety, I give bromide of sodium in Squibbs's fluid extract of ergot, 15 grains to a teaspoonful. The dosage of galvanism in hemicrania should be a current of from 1 to 3 milliampères, seldom 5, continued from two to three minutes, daily at first; then, as improvement takes place, on alternate days. The same rule as to frequency of administration holds good for static electricity as well.

Hemicrania does not always manifest itself in one of the forms indicated. It may also appear as a mixed variety, in which the symptoms of the two varieties alternate; or there may be periodic attacks, in which the sensory and oculo-pupillary phenomena occur without pain,—a hemicrania without headache. An interesting case recently came under my observation, in which, at first, the phenomena were of the classical type of hemicrania, associated with peculiar pupillary phenomena which always preceded the attack. At one time there would be a right, at others a left, bilateral hemianopsia, usually associated with the appear-

ance of a zigzag band of phosphorescent light. Examination of the eye during an attack revealed nothing abnormal. After some eight or ten years the headache disappeared, and the attacks, which were very irregular, came to consist of the eye-symptoms, with sometimes slight subsequent headache. This case, however, may well have been of hysterical origin. Gilles de la Tourette has recently called attention to the fact that out of thirteen cases of hysterical ophthalmic migraine four presented the phenomenon of a transitory hemianopsia. In these mixed cases galvanization as used in the classical forms, combined with simple insulation, is indicated. Every effort should be made to raise the tone of the nervous centres to the highest possible point.

Insomnia.

So little is known absolutely of the condition of, and changes in, the brain during sleep that as yet no method for the treatment of insomnia can be founded upon that basis. The treatment, therefore, is empirical. Electricity is used in insomnia because it has been found useful for the reduction of the condition, which is in itself only a symptom of many diverse disorders. Electricity has frequently been noticed to increase sleepiness in patients who resorted to its use for other purposes,—and this before treatment had been sufficiently long continued to account for the result by the relief of the symptoms. The application of electricity is especially useful in insomnia accompanying nervous and mental disorders, and it should be used more than it is as a hypnotic, since it is free from the bad after-effects and the danger of the formation of a habit, to which most sleep-producing drugs are open.

MacFarlane (" Insomnia and its Therapeutics ") states that he has found it beneficial in about three-fourths of the patients who have used it for insomnia; in some cases the improvement was very rapid, but in the majority came more slowly. He recommends very weak and prolonged currents,—an application of twenty minutes and upward, on alternate days. He uses first longitudinal galvanization, with the anode at the forehead; then subaural galvanization, anode under the jaw; and afterward stronger currents, from the anode on the cervical vertebræ to the cathode over the epigastrium; and, lastly, a current from the anode on the cervical vertebræ to the cathode in a foot-bath. Althaus uses gentle galvanic currents from five to ten minutes. Steavenson and Jones recommend general faradization, or the faradic bath, as the best method of application for the relief of insomnia. In my own practice I am in the habit of giving longitudinal galvanization,—a current of 1 to 3 milliampères from two to three minutes,—with the actual cautery at base of brain, directing that after treatment there shall be no mental work and no avoidable excitement. The operator must be very careful not to be abrupt in turning the current off and on. As the use of elec-

tricity sometimes fails to produce sleep and aggravates all the symptoms, its effects must be carefully watched.

A trial of electricity may be made in such affections as hydrocephalus, chronic meningeal affections, diffuse peri-encephalitis, sclerosis, etc. Unexpected amelioration, or even recovery, is said to sometimes occur under its use. The treatment consists in longitudinal and oblique galvanization of the brain, subaural galvanization, and galvanization of the cervical cord. If electricity is tried in chronic meningitis, very large electrodes should be used. The best results will probably be achieved in chronic basilar meningitis. In this trouble I have observed unquestioned benefit from the use of voltaic alternatives. In one case the patient was absolutely unable to write when he came to me, talked with great difficulty, and was of unsteady gait. After three months' treatment he could write as well as ever, his speech was greatly improved, and his gait was nearly normal. The galvanic current is used in cerebral syphilis directed against the symptoms,—headaches, insomnia, paræsthesiæ, etc. Althaus thinks its greatest efficiency in these cases lies in its power of promoting collateral cerebral circulation. In my own experience the use of electricity has been altogether disappointing in cases of this sort. Electricity has been used in athetosis, but the results have not been encouraging. Erb reports one instance of amelioration in a case under his care.

NEUROSES.

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Mode of Action of Electricity in Neuroses.

Neuroses are, *par excellence*, the kind of nervous disease in which favorable results are obtained from electrical treatment. More or less doubt may be entertained whether electricity may alter for good or for evil such disease processes as cause organic change in the central nervous system, but any one who has had extensive experience in treating functional nervous affections with electricity must either bear witness to the favorable results observed or else lay himself open to the suspicion that he has not the skill and judgment necessary for its proper employment. Of course, in some kinds of neuroses and psychoses its effects are more marked than in others, while some may be absolutely rebellious to its influence. But the same is true of all therapeutic agents. It is also true that some physicians are less successful than others in using electrization, —a difference which, it may be suspected, depends in part upon the judgment with which suitable cases are selected for treatment, and in part upon the skill with which electricity is applied. This general statement of the beneficial effect of electrization in this class of diseases is not a committal to any particular theory of its mode of action. It does not imply that electricity must have a specific influence as electricity on the nervous elements, or that its curative results are brought about in a way other than that of reflex stimulation of the skin and peripheral nerves; indeed, it is not incompatible with the belief that the therapeutic effects are due entirely to the mental effect or suggestion. Whatever its mode of action, the treatment of neuroses by electricity is often followed by beneficial results.

At this point, then, it will be well, once for all, to consider the modes of action of electricity, in order to avoid repetition when, later, we discuss the treatment of the different neuroses by themselves. It will then be understood that all that is necessary has been said in this matter. There are several ways in which electricity is capable of action on the nervous system so as to produce its therapeutic effect, although it is not always easy to determine the one that is active in individual cases.

Considerable skepticism has been awakened of late years regarding the possible specific action of electricity in curing disease. The exaggerated claims of the earlier observers of the power of electricity to cure organic disease, such as cerebral hæmorrhage, spinal sclerosis, etc., have led to a reaction which not only denies all curative influence in such

affections, but attributes all the beneficial results which are obtained in functional diseases, and which are beyond question, not to the physical effects of the current, but to the psychological impression produced.

The power of suggestion to modify functionally-diseased states has been brought into prominent notice of late by the study of hypnotism, and the therapeutic results obtained by hypnotic suggestion have offered a new explanation of many of the phenomena obtained in every department of therapeutics. The inference was natural that the effect of electricity in functional disease might be due to suggestion pure and simple.

That the electric battery, and especially a static machine, can be made to have a powerful suggestive influence on a patient's mind is a fact that can be easily demonstrated. It is beyond question that the electric current, in many instances, acts in this way, and that some of the more brilliant cures are due to suggestion, and to suggestion alone. I have myself, again and again, made use of this suggestive influence, and obtained very striking results. In fact, whenever I wish to make use of suggestion for therapeutic purposes, it is my habit to employ the battery [1] as an agent. Very pretty experiments may be made in this way, showing the power of suggestion in the waking state, even without hypnotism. If any one doubts the suggestive power of many of our therapeutic agents, he has only to make a few experiments of this sort. That the results in such cases are due to suggestion cannot be doubted. It is possible to play upon the nervous systems of some patients as readily as in the hypnotic state. Susceptible subjects will experience just such feelings and be relieved of others, as the operator "suggests." One has only to assert boldly that the patient will experience this or that sensation, and, if the subject is a suitable one, the prediction will be fulfilled. If more evidence is wanted that these results are due to suggestion, it may be obtained by shutting off the current from a galvanic battery without the knowledge of the patient.

These facts are very important, and must be borne in mind by him who would form a sound judgment on the action of electricity.[2] The case of paraplegia cited on page K–46 may be referred to here. The cure, in this instance, effected by "electric suggestion," was literally so electrical as to seem to the patient to partake of the nature of a miracle.

But though the electric battery may be made to produce results of this nature, the same may be said of almost every other therapeutic agent, medical or surgical. The physician who, believing implicitly in the efficacy of his treatment, never prescribes a dose or applies a blister without giving positive assurances of the beneficial results that will follow, will always count a higher percentage of cures, when dealing with functional diseases and minor ailments, than the skeptical and timid practitioner. The electric battery is particularly well adapted to pro-

[1] The static machine is most effective for this purpose.

[2] The same may be said of many other therapeutic agents, such as blisters. Compare, for example, Harkins's cases, cured by blistering over the fourth and fifth cervical vertebræ.

duce a profound impression of this sort on the mind. But he is a rash generalizer who would infer from such facts that this is the only way in which electricity acts. A generalization of this kind rests on even less substantial evidence than that which attributes to the electric current the power to reorganize structures irreparably destroyed. One might as well infer that, because in given instances bromide could be shown to produce sleep by suggestion, it had no physical hypnotic effect. It may be said that electricity can act, and in many cases does act, by suggestion, but, with our present knowledge, more than this cannot be said.

On the other hand, it has been found that electricity does produce certain physical reactions in the body, and there is good reason to infer that it is through the medium of these reactions that the beneficial therapeutic effects in psychoses are brought about.

The physical facts, by means of one or more of which the therapeutic effects of electricity may be brought about, may be briefly described as follows :—

1. The compound group of phenomena known as catalysis.[1]

2. Changes in the circulation of the brain and spinal cord, which have been observed to follow electrical stimulation of the skin. (Nothnagel observed contraction of the cerebral blood-vessels following electrization of the skin and of the sensory nerves. These results have been confirmed by Rumpf, who found that faradization of the skin of a limb caused transient anæmia, followed by congestion of the opposite hemisphere.)

3. Changes in the circulation of the brain, shown by Löwenfeld to occur in rabbits when an electric current is passed in different directions through the head. According to this observer, when the positive pole was placed on the forehead and the negative pole on the nape of the neck a contraction of the blood-vessels of the brain occurred, but when the poles were reversed a dilatation of the vessels resulted. When the poles were placed on the side of the head a contraction of the vessels lying beneath the positive pole was produced, and a dilatation of the vessels on the side on which the negative pole was placed.

4. More important than all, certain changes, as yet of an unknown nature, produced in the central nervous elements by reflex stimulation independent of the circulatory changes.

The effects included in this fourth class receive a certain explanation from what we know of the effect upon the body of reflex stimulation by physical agencies other than electricity. The readiness with which the central nervous system may be affected for good or for evil by different kinds of peripheral stimulation is a fact too well known to need reiteration, but the intensity of the effect that may be produced by such stimulation, even on parts of the nervous system not directly connected with the particular centripetal nerves acted upon, is apt to be overlooked in

[1] Catalysis was introduced by Remak as a convenient term to designate a number of complex physical effects of the electric current. They are thus summed up by de Watteville :—

1. Its property of conveying liquids from pole to pole (cataphoresis and osmosis) through the tissues, whether cell-walls or intercellular material.

2. Its property of inducing chemical changes in solutions through which it circulates (electrolysis).

3. Its effect on the circulation of lymph and blood through the tissues. This effect is (*a*) direct (by excitation of the vessels themselves); (*b*) indirect (of vasomotor or sympathetic nerves); (*c*) reflex (of sensory nerves).

To which list we may add (4): Its possible excitation of the trophic influence of nerves on tissues; and of their constituent cells themselves.

individual instances. Counter-irritation is a classical instance of such action. Heat and cold are capable of producing very profound effects upon the nervous system, whether in the form of douches, ice and hot-water bags, hydrotherapy, or the atmosphere. The undoubted beneficial influences of hydrotherapy can only be attributed to the stimulation of the peripheral nerves. The tonic and depressing influence of the atmosphere is a matter of such familiarity that it is apt to be overlooked; yet, when one pauses to consider the profound effect on the well-being of the individual, at times produced in a very few minutes by sudden changes in the temperature of the atmosphere, one can hardly help being astonished. An instance of this, which has probably been experienced by every one, is the tonic, bracing effect almost instantly felt when, after a hot day in the city, one feels the cool sea-breeze on a harbor steamer. The physical depression caused by the city's heat and day's work disappears as if by magic. The change is too sudden to be due to the cooling off of the body, but the feeling of well-being must be due to stimulation of the peripheral nerves. This is in line with what is known of the tonic, bracing effect on the nervous system of the cold air of high altitudes. It is generally conceded by writers on Alpine health resorts that this is one of the principal factors which give these places their therapeutic value.

The power of smelling-salts to relieve headache, remove faintness, etc., is too well attested to be doubted.

These commonplace facts are referred to here because they are similar in character to many of the effects produced on the central nervous system by electricity, and throw a side-light on its mode of action. I have frequently noticed, as has, probably, every observer, the same physiological phenomena after electrization. Patients often describe the same sensations of well-being, of increased energy, and of a sense of exhilaration while being electrized as from a cold douche or a sea-breeze, etc. It seems to me that these effects are best explained by stimulation of the peripheral nerves. Further evidence of this mode of action is the unfavorable effects sometimes produced. It occasionally happens that patients do not bear electricity well. In such cases various unpleasant symptoms are produced; headache, vertigo, faintness, various paræsthesiæ, pains, nervousness, and sleeplessness are experienced. These seem to be the direct result of the irritation of the nerves.

Rockwell says he has repeatedly seen the pulse-rate (in a case of neurasthenia with rapid pulse) reduced 40, 50, and 60 beats. I have seen the pulse fall 20 beats under similar conditions. Przewaski observed the temperature of one side of the face reduced from 0.5° to 0.175° C. by subaural faradization. This, as well as the fall of temperature of the skin between the third and fourth fingers on faradization of the ulna, was, however, probably due to contraction of the vessels. Weir Mitchell has demonstrated the rise of the general temperature of the body after general faradization.

Further direct evidence of the reflex influence of centripetal stimulation is the sweating sometimes observed following static electricity. The fact that peripheral irritations tend to diffuse themselves along other associated tracts that are in close connection with the nervous centres primarily stimulated may sometimes be observed in painful affections like neuritis. In a case of inflammation of some of the branches of the brachial plexus I frequently observed that the pain, after it had persisted for some time in an intense form in the original nerves, spread to the districts supplied by neighboring branches, then to the neck, side, and, finally, leg of the same side. This mode of propagation was very much like that of the discharge of an epileptic fit.

A curious though simple phenomenon of cutaneous irritation, and one which I have never before seen mentioned, is the following, which I have frequently produced on a certain subject: On scratching the skin on the outside of the thigh, a very intense, sharp, stinging pain on the same side of the body over the lower ribs has been felt. The pain is very sharply localized, and feels as if the skin were pricked acutely with a needle. It can only occasionally be excited, but on favorable occasions it is very easy to elicit it. This is evidently a reflex pain, due to slopping over of the stimulation to associated centres.

The exact mode in which electrical stimulation—as well as that of other agents—acts upon the central nervous system is, of course, hypothetical or unknown. But its influence evidently extends beyond the centres directly connected with the centripetal nerves. It undoubtedly has an inhibitory influence on associated centres, as in the suppression of pain and headache, and it seems to have the power to restore the nervous equilibrium, so to speak, when disturbed. It also seems to have the power to arouse into activity nervous centres which temporarily, from functional causes, have been dormant. Deeper than this it is not to be expected that we can go.

When, then, the effects of other forms of peripheral stimulation, a few of which have been mentioned above, are recalled, and when we bear in mind the immense number of cutaneous nerves that can be brought under the electrical influence, and the intensity of stimulation that can be obtained of the central nervous system, it is not so very surprising, after all, that electrization should be so effective a mode of stimulation.

Psychoses.

Arndt was the first to make a systematic and extensive study of the effect of electricity in mental affections. The results obtained by him were of an encouraging character. A number of other observers, for the most part in Germany (Schule, Morel, Emminghaus, Benedict, and others), have reported cases which were cured by electricity. On the whole, the results achieved thus far have given promise that in electricity we have an agent capable of influencing beneficially a certain class of

cases of this kind. The method has not, however, been as systematically pursued as it should be. Whether it is that the helplessness of attempting to effect the graver forms of mental disease by such an agent has thrown a damper over the courage of the alienist, and produced a skepticism regarding the possible curative influence in the lighter cases, even in their earlier stages, or whether it is that alienists, as a general rule, have not that familiarity with the use of electricity which would stimulate them to more systematic trials, while electrical therapeutists are not sufficiently often brought in contact with cases of psychoses,—whatever be the reason, the treatment of these affections by electricity has not been pursued as systematically as is desired. The observations thus far made, although there could be many of them of a favorable nature, have been comparatively scattered and limited. Erb wrote, in 1887: "We have been unduly backward with regard to the systematic and extensive employment of the electric current in one group, and that one of the most important of cerebral diseases. The psychical affections have, until now, been subjected to electrical treatment very seldom, and in a manner that has been quite insufficient." The same statement is true to-day; in this country, at least.

It may be said, however, that it is not in asylums that cases will be found suitable for this kind of treatment. Cases sufficiently grave to be committed to asylums are generally too far advanced or too serious to be affected by electricity. It is rather in the lighter or border-land cases that favorable results are likely to be obtained by this mode of treatment. And yet quite a number of cases of a severe type have been reported in which the curative effect of electricity was quite marked. Referring here only to some of the later observations, mention may be made of a series of eleven cases (ten being of melancholia), carefully observed and reported by Wigglesworth,[1] in three of which a cure resulted under treatment by galvanism, and two were thought to be benefited. Of the three cases discharged cured, one had existed over two years previous to treatment, and was convalescent in about forty days, after sixteen sittings. The author concludes, as a result of his experience, that the use of galvanism is followed by good results in selected cases, which might otherwise drift into hopeless chronicity. He believes that mental stupor, torpor, melancholia, and acute dementia are particularly benefited by galvanism. These cases by themselves, without additional corroborative testimony, are hardly sufficient in number, nor were the results sufficiently brilliant (judging by the report) to justify the conclusion that galvanism was the active agent in bringing about the final result. There is, however, more testimony bearing on the point, which, though scattered, is of value.

A very remarkable case is one reported by Robertson. It was a case of melancholia, with delusions of suspicion, for which the patient,

[1] Journal of Mental Science, No. 33.

a woman 50 years old, was committed to an asylum. Imaginary voices affected her very much, and in time she refused food so that she required feeding by the stomach-pump. In October, 1882, when galvanism was begun, her condition was worse than when she entered the asylum, fifteen months previously. Up to this time she had been insane seven years. After the third application she began to improve, and in the following March was discharged cured, but it was noted that she had been free from symptoms for two months. A current from 15 to 20 cells was used. The patient was so convinced of the benefit derived from the battery that she asked to have her hair cut very short in order to get the full effect of the current. She attributed her recovery to the battery.

Erb, in his hand-book of electro-therapeutics, has given a summary of the observations, mostly favorable, of Arndt, Benedict, Neftel, Franz Fischer, Tigges, and others, to which the reader is referred. It is folly, however, in spite of occasional brilliant results, to expect to find in the electric current an agent which can be relied upon in the severer psychoses. We could hardly expect better results than those obtained by J. Morel[1] in melancholia, mania, paranoia, and dementia. Electricity had but slight effect in these cases, excepting that in 15 out of 96 cases of melancholia the results were very good. In 16 others they were less gratifying, while in the remainder there was no, or only temporary, improvement. As has already been said, it is only in the initial stages of the milder psychoses that electricity will have a favorable influence. More promising are those cases where various psychical disturbances are engrafted on other co-existing physical states, such as neurasthenia, hysteria, epilepsy, traumatic psychoses, etc. Cases of this kind are very numerous, and come under the observation of the general practitioner and the neurologist rather than the alienist.

It is not possible, with our present limited experience, to define, except in a very general way, exactly what cases are benefited by electrization. Examination of the literature shows a heterogeneous assortment thus far reported, and further systematic observation is necessary to determine what class is likely to be favorably influenced and what class not. Melancholia sometimes, even in a severe form, has been frequently cured, and some cases even of primary dementia have given favorable results, but the latter must be regarded as exceptional. Although all kinds of insanity have been treated, it is absurd to expect electricity to influence such diseases as mania, general paralysis, secondary dementia, paranoia, or melancholia in its severer forms. But milder psychoses, conditions which may be supposed to be dependent on neurasthenic conditions, various functional disorders, such as impaired nutrition, derangements of circulation, or a morbid association of ideas may often be cured, even though hallucinations, delusions, etc., be present. The results of observa-

[1] "L'electro-thérapie dans les Maladies Mentales"; Bull. de la Société de méd. ment. de Belgique, 1889, Ma., Nos. 52, 27.

tions, thus far made, indicate that it is desirable that a more extensive trial should be made of the treatment by electricity of cases of this kind. The field is a promising one. As Erb says, "A general survey of the observations, with regard to the electro-therapeutics of the psychoses, which have been made up to the present time, shows us that the psychoses can, in certain cases, be favorably influenced and sometimes cured by the electric current, even in cases in which all other possible remedies have long been tried in vain."

The writer has made no attempt to treat with this agent the graver psychoses, such as are suitable for asylum care, but has had considerable experience with the lighter forms. The results have been satisfactory, particularly when the psychical symptoms were the manifestations of other physical conditions. Such patients, it is true, were not strictly insane, but the psychical symptoms were sufficiently prominent and persistent to create a distinct psychosis, for which the patient sought treatment. The following are examples of the class of psychoses likely to be benefited:—

Personal Observation 1.—Mrs. D., aged about 42 years; ill for two years. Fixed idea that certain persons have hypnotic influence over her, and that she influences others. Interprets every action of others, including strangers, through this idea. Cannot ride in horse-car or go to church in consequence of hallucinations of vision; sees faces of certain individuals. Insomnia, general neurasthenia. Out of bed only three or four hours a day. Mental depression. Various perverted bodily sensations, such as pain, etc. Treatment: Static electricity three times a week. Improvement immediate. Slept well; hallucinations gradually disappeared. Fixed ideas less insistent and less constant. At the end of about two months patient could work greater part of the day, and, though not strong, could do much. Insistent ideas present only when tired, and in mild form. [Patient discharged, partly because nearly well and partly because it was not practicable to continue treatment. She had been sent to me by one who had had a large experience in asylums, with the prognosis of a hopeless case, and prophecy of early commitment to an asylum.]

Personal Observation 2.—Mrs. W., aged about 40 years. As a result of experimenting with spiritualism and mediums, had developed a psychosis. Against medical advice she had tried to develop herself into a medium. Symptoms: Great mental depression (melancholia); hallucination of visions; insomnia; insistent ideas; local pain. Treatment: Static electricity. Improvement began at once and continued. Cured after about three weeks' treatment.

Personal Observation 3.—Mr. D., aged about 45 years. Subject to ambulatory epilepsy. Medical advice sought by his wife because of melancholia and suicidal impulses. Depression marked. On first appearance he was the picture of misery. Although formerly an active business man and full of energy, he had become unable to perform any business, etc. Insomnia. Treatment: Static electricity. Improvement immediately after first sitting. After about ten sittings, well.

Symptoms which have essentially a psychical origin, whether they be pain, paræsthesia, insomnia, or many of those strange, "queer feelings in the head" or elsewhere, which patients find great difficulty in describing, are, as a rule, favorably influenced by electricity.

TECHNIQUE OF TREATMENT.

The customary method is to apply the electricity to the head, although it is recommended by some to galvanize or faradize the spine

and "sympathetic" and peripheral nerves. Minute rules have been given by German writers governing the use of the different poles and the duration of the current. For example, it is laid down by Arndt that when well-marked irritation is present the descending current should be employed,—that is, the anode on the head, the cathode peripherally; but if a state of depression or torpor exist, the ascending current should be used,—the cathode on the head, and the anode peripherally. In other words, if an exciting action is desired, the cathode is selected, and if a sedative the anode. Löwenfeld goes one step farther, claiming, as a result of his experiments on rabbits, that when the anode is placed on the nape of the neck and the cathode on the forehead,—the ascending current,—the vessels of the brain are dilated and the circulation accellerated, while, if the electrodes are reversed and the descending current used, the vessels are contracted and the circulation retarded. Therefore, when a state of hyperæmia is present, the anode should be placed on the forehead and the cathode on the nape of the neck, and *vice versâ*. But granting the applicability to the human brain of results obtained in experimenting on rabbits, an inference of which the questionability has been pointed out by Erb, we know too little of the condition of the circulation in psychoses to make these physical principles of any value. But even Erb, who perceives the flimsiness of the evidence on which rules of this sort are based, cannot quite free himself from the force of authority, and so his work on electro-therapeutics is in many places a painful exhibition of the struggle of a scientific mind to reconcile the traditionally accepted and pleasing, but imaginary electro-therapeutics of his predecessors with what is really known of the action of electricity on the body in health and disease.

Now, supposing a condition of anæmia or hyperæmia to be present in melancholia or dementia, have we any means of determining what relation this supposed condition of the circulation bears to the disease itself, whether that of cause or effect, or whether influencing the circulation would influence the disease? Similar questions may be raised as to the use of the anode and descending currents to produce sedative effects, and *vice versâ*. I do not question the fact that the physiological reactions of the two poles in some respects differ, and that occasionally results are obtained with one pole that the other pole fails to give; but the physiological reactions furnish no basis, and the therapeutic results a very slender one, for any system of treatment of this kind. In the great majority of instances one pole is probably as effective as the other, and where there is a difference it may, perhaps, be explained by a difference in the intensity of the action. With a few exceptions, with a current of the same strength, the cathode has more intense action than the anode; but if the current be decreased while the cathode is the active pole, the intensity of the action will diminish till it equals that obtained with the anode with the original current. The supposed sedative action of the anode may be due to its quantitative and not qualitative effects. In

peripheral electrization the reason for this becomes plain when it is remembered that it is probable that the principal mode by which electricity acts on the central nervous system is reflex through the afferent nerves. It is the excitation of the nerves which brings about the central changes; this means that it is neural molecular motion, and not that form of molecular motion which is known as the electric current. Now, obviously, we should *a priori* expect that it would be a slight matter whether this neural motion (current) were excited by a positive or a negative anode, or an ascending or a descending electrical current. When Rumpf found that faradization of the skin produced contraction of the cerebral vessels, the immediate agent was the neural current in the afferent nerves, and not the electrical current.

Turning from these theoretical considerations to practical experience, it seems to me that these views find ample confirmation in the equally successful results obtained by different and opposing methods. One hesitates to throw overboard the experience of other observers without weighty evidence, but I must confess that, allowing for this difference in the intensity of action of the two poles, my own experience has failed to convince me of a difference in the quality of their therapeutic effect. Erb speaks with great caution in the matter, and, although believing in a difference in the polar action, admits that our use of them must be largely empirical; and de Watteville, whose discussion of the subject is by far the most scientific and sensible that has yet appeared, is still more skeptical. Until, however, the matter has been settled one way or the other, many physicians will prefer, as de Watteville advises, "to observe up to a certain point the polar dictum," and use the positive pole when a sedative effect is desired, and the negative when a more exciting one.

The pathogenesis of many psychical affections is too obscure to allow ourselves to be governed by theoretical physiological principles in using electricity. The formulæ of electro-therapeutics rest only on empirical data, and the best methods are those which experience shows give the best results. While different observers have their preferences, equally good results seem to be obtained irrespective of the direction of the current or the pole used. As de Watteville expresses it, "The position of the pole in therapeutic applications is to be governed chiefly by physical principles; it must be such as to secure the most complete permeation of the organ or tissues to be influenced by the current."

In applying galvanism to the head, my own method is to try and saturate, so to speak, the whole brain with the current, unless there is a specific reason for localizing it on a special region. With this end in view, it is passed longitudinally from forehead to nape of neck, and longitudinally through the temples or parietal regions. I use a current as strong as can be borne without producing vertigo, beginning with 0 and gradually increasing to this limit without removing the electrode from the skin. Before removing the electrode the current is gradually

diminished. Shock must be avoided. A sitting should last about ten minutes.[1] An electrode covering the head in the form of a cap may be used, the other electrode being applied to some other part of the body. When the *faradic* current is used it is not necessary to use the same precautions in regard to increasing or decreasing the current when applied to the head. This current is considered by some to be more stimulating and more efficient in cases of stupor or depression.

Galvanization and faradization of the peripheral nerves are strongly recommended by Arndt, who used this method principally in his earlier observations. For this purpose general electrization, after the method of Beard and Rockwell, may be used as described on page K–59. This should be particularly serviceable when neurasthenia exists. It is very refreshing and stimulating when properly done.

To obtain the best results with electrization considerable judgment and skill are essential, especially with the class of cases we are considering. It seems to be a very simple matter, but experience, in this as in everything else, is a great advantage, and he who possesses it will obtain results which another will strive for in vain. Some persons—neurotic subjects—are very sensitive to electrization, and when it is carelessly done unpleasant consequences are likely to ensue. I have seen this illustrated in more than one individual, who, though affected most favorably by electrization, developed most disagreeable symptoms if I became careless in applying it. I have used *static* electricity in the mild psychoses with marked success. This form has the advantage that it can be applied to the head and the body without the inconvenience of removing the clothing. For the head the static douche, or breeze, is most advantageous. Many unpleasant symptoms are readily dissipated by it. Mental depression and insomnia often yield after a few applications. Local symptoms in different parts of the body, but of a psychical origin (pain, paræsthesia, etc.), can sometimes be suppressed at once. For this latter purpose a mild spark is best. It is not necessary to have sparks stronger than can be borne without effort, but when the local distress is severe it is often surprising to see how strong shocks a patient can bear, and even court, without flinching. A well person will rarely endure so much. For methods of using static electricity, see article on that subject (A–84) in this work. For mental depression and other psychical symptoms, I would recommend allowing treatment with head douches for a relatively prolonged sitting,—say, twenty minutes to half an hour. Finally, it may be said that individual symptoms in the psychoses, when suitable for electrical treatment, are to be treated as in other diseases.

[1] The rules given by some writers are absurdly cautious. One or two minutes and 2 or 3 milliampères are stated to be the limits of time and strength. Excepting in individual cases, which exhibit great sensitiveness, these are unnecessarily small. Rockwell speaks of having given 33 milliampères. The best guide is the sensation of the patient. A current less than that which will produce vertigo is safe. I have never seen any reason to think ten minutes too long, nor that this time might not be prolonged, but it is true that over 4 or 5 milliampères will usually, not always, produce vertigo or other disagreeable symptoms.

Regarding the *choice of the different varieties of electricity*, static electricity certainly has more suggestive influence than other varieties, but whether it is more effective in other ways may be doubted. I am inclined to think, though, that a static spark is most effective in psychoses in relieving pain located in distant parts of the body, but of a psychical origin. Still, sometimes one variety is most effective and sometimes another, and it cannot always be determined without trial which will prove the most suitable in a given case. But for application to the head experience seems to have shown that galvanism or faradism is most efficient in the great majority of cases. It is well to begin with one of these, and then, if the results are not satisfactory, to shift to one of the others. It is even well, during the course of prolonged treatment, to change from one to another, as we would change in medicinal treatment from one tonic to another. For electrization of the peripheral nerves for purposes of stimulation, faradism is usually the more effective. It is particularly important, when using general faradization, not to use a strong current. A general stimulation of large surfaces and many nerves produces much more favorable effects. To relieve local pain, such as a painful spine, galvanization or faradization should be selected.

Hysteria.

The results of the electrical treatment of hysteria are very uncertain. Sometimes very brilliant cures are met with; at others, hysteria is as rebellious to electricity as to everything else. This difference depends in part upon the varied character of hysterical affections, and in part upon wholly unknown factors. Some writers claim that electricity has a specifically favorable influence in hysteria; others, like Erb and de Watteville, that it is very unreliable. This diversity of opinion depends largely upon the difference of view as to what shall be classed as hysteria. In cases where the symptoms may be properly classed as hysterical and symptomatic of, or a complication of, some other disease, electricity may justly be said to have a beneficial influence. It is well known that even in organic disease many symptoms of a functional (hysterical) nature may be superimposed upon those due to the primary disease. In neuritis, for example, or cerebral hæmorrhage, an anæsthesia may be added of a purely functional nature. In other cases, a localized paralysis may become widely distributed over other parts from the same reason. In neurasthenia many of the symptoms may be purely hysterical, and may be so marked as to mislead us as to the true character of the disease. Anæmia may present a variety of hysterical symptoms, which may overshadow the true pathological conditions present.

Sometimes it happens that an organic disease, such as a neuritis or an arthritis, turns into an hysterical affection of the same parts, in which case the transition is often overlooked until a sudden cure takes place to the surprise of the physician. For example, I recall a severe case of in-

flammation of the brachial plexus, causing paralysis and atrophy of the muscles supplied by the nerves. At the end of about eight months there was no improvement of the paralysis, but loss of power appeared in the other arm. One day, in a fit of emotional excitement, the patient threw up her arms, and she was cured. All the symptoms of neuritis (pain, glossy skin, atrophy, etc.) had been present in the arm originally affected. The neuritis had healed without the fact being suspected. A student received an injury to the knee from a fall while playing foot-ball. There was no abatement of the symptoms during several months, until one day he threw away his crutches and walked off well.

Organic injuries of one part are apt to induce functional disturbances of other parts. Hysterical neuralgias are very common accompaniments of various diseases. A mild neuritis of the arm was accompanied not only by excruciating pains of the same limb, but also by pains in the neck, side, and corresponding leg. The course of events showed all these secondary pains to be functional. Whether such conditions should properly be classed as hysterical may be questioned, though, as a matter of fact, in practice it is usual to find them so considered. The same is true of a great many minor functional disabilities, some of which, at least, I must consider as more properly belonging to habit neuroses, association neuroses, auto-suggestion, and what not, while others are hysterical psychoses.

Now, I think, it is within the limits of moderation to say that such minor affections as these, as well as the hysterical factor complicating other diseases, are, as a rule, readily cured by electrization. Hysterical neuralgias complicating other affections are often dissipated as if by magic. They often return, it is true, as long as the primary disease persists, but they are easily held in check by repeating the treatment. Narcotics and other drugs are thus dispensed with. It would seem that cases of this kind are very different in their pathology from those in which the physical defects present are but manifestations of what may, for want of a better name, be termed the hysterical diathesis. When this is present, underlying the paralysis, or anæsthesia, or convulsive seizures, there seems to be a morbid condition of the nervous system, of which these stigmata are the symptoms.

Given a case of hysteria of this kind, it is pretty safe to count upon its being rebellious to all electrical treatment. By this I mean cases of monoplegia or hemiplegia of the Charcot type, with implication of the special senses; cases of hystero-epilepsy, ataxia, hysterical contractures, joint disease, and of hysterical hemianæsthesia. In each of these diseases the type is well and sharply defined, so that it may be classified as specifically and distinctly as pneumonia or typhoid fever. Such cases are difficult to cure by any mode of treatment. This is particularly true of paralysis, etc., due to traumatism, especially when litigation is in progress. And yet it sometimes happens that individual

cases rapidly improve under electrization, while others quite obstinately resist.

In illustration of this last statement the case of a young girl who was paralyzed in consequence of a blow on the top of the head by a piece of shafting may be cited. An hysterical paralysis, with anæsthesia of the left leg, of moderate intensity, developed. The left hand was also weaker than its fellow. The special senses on the left side were affected, and the field of vision was also much contracted for colors, as well as for white light. Under electrization the patient improved, and in a short time was practically well. Another case of hysterical paralysis of the muscles of the back following a fall was much improved after a few sittings, though she returned to her home in the country before the cure was complete. But in contrast with these favorable results other cases might be given where no benefit whatever was derived.

It almost seems as if some cases of hysteria, especially monoplegia of the Charcot type, waited until they were ready to get well, and then got well of themselves. Such kinds of hysterical paralysis may persist for years. I have known three cases to persist for twenty-five years with little change.[1] Because of the suddenness with which cure sometimes takes place in hysteria the impression is current that this is to be expected ordinarily. This is a mistake. As a rule,—at least, this is the writer's experience,—hysteria yields gradually to treatment like other affections. The general physical condition needs to be treated as much as, if not more than, the motor and sensory phenomena. The strongest moral influence must be brought to bear, and unhealthy mental surroundings removed. Isolation from home and friends, in most cases, is all-important. As an adjunct, electricity is often of service, and sometimes its effects in dispelling local stigmata are striking. In applying electricity for the cure of hysteria, it is important to use it so as to obtain a powerful moral effect; that is, suggestion plays an important, if not the principal, rôle in producing the cure; as witness the well-attested cures effected by metallo-therapy, as well as many of the phenomena produced in hysteria by magnets. A wooden magnet is just as effective as a real one. Some curious experiments illustrating the force of suggestion were made by Babinski[2]:—

Two hystero-epileptic girls, each of whom presented hemianæsthesia, were seated back to back, and then a magnet was placed upon the arm of one of them. In a short time one of the girls was entirely wanting in sensibility, while the other recovered it. Afterward the conditions were reversed, and there followed a series of oscillations. The hemianæsthesia quickly returned to both girls upon their being separated. The transfer from one to the other took place more quickly if the backs of the patients touched, but also took place when there was a distance between the two. A paralysis, induced by suggestion, in one of the hysterical patients could be transferred to the other by the method above described. The same was found to be true of coxalgia, dumbness, and a somnambulistic condition, When patients who had come to the hospital with an hysterical paralysis not arising from

[1] Amer. Journal of the Med. Sci., 1892.

[2] Progrès Méd., xiv, 47, p. 1010, 1886.

suggestion were seated back to back with one of the hysterical individuals just mentioned, who was in a somnambulistic condition, and the magnet was applied, the corresponding paralysis of the former appeared in the latter, even although the former remained paralyzed.

It would be easy to multiply the evidence of the suggestive power of electricity in hysteria, if it were necessary. It is not entirely, however, by suggestion, that electricity acts. The local shock, or peripheral stimulation by itself, is equally capable of removing hysterical manifestations. For instance, in one case I accidentally, and contrary to my purpose, caused complete anæsthesia of the hand to disappear by means of the electric needle. I was experimenting for another purpose, and was not myself prepared for the unexpected result, nor was the patient. The consequence was, the experiments could not be carried out. It is well known that a local shock from other means—as, for example, the actual cautery, a cold douch, emetics, etc.—will sometimes cure hysterical symptoms. Just as powerful irritations will cause hysteria, so they may cure it. A wise physician will, therefore, take advantage of all the therapeutic aid which electrical treatment offers in hysteria—of the mental as well as the physical impression; neither should be neglected. It is justifiable, as well as desirable, to attempt to arouse an expectant condition of mind in the patient as to the results that will follow. For this purpose it is imperative that positive assurance should be given of the result that will follow. The patient should be encouraged to regain the dormant willpower. The physician who is timid or hesitates is lost. It is well to persist at each sitting until some degree of improvement is manifested. Strong currents or shocks are, as a rule, more efficient than mild ones; it is therefore important to use as strong a current as can be comfortably borne, but it is not necessary or desirable to be severe.

Regarding the *choice of kind of electricity*, it will be found that sometimes one kind is more effective and sometimes another. Probably, as a rule, faradism is more efficient in curing motor defects and static in relieving sensory symptoms, although I am not aware that any systematic observations have been made to determine this matter. It is only possible to state a general impression, which has been derived from experience. The powerful muscular contractions that may be evoked by faradism render it particularly serviceable in paralysis. On the other hand, pain, paræsthesia, and anæsthesia are often more readily dissipated by static electricity. The awe-inspiring nature of a powerful static machine make it especially suitable for producing a profound effect on the mind of the patient.

Static electricity often gives successful results in the treatment of motor as well as sensory symptoms. Of late years this variety has been much used, and in a great measure has superseded the galvanic and faradic currents in the treatment of neuroses, largely because of the convenience with which it can be applied, and its adaptability to a variety of

different conditions. By means of Morton's electrode and method, it can be converted into the dynamic variety, and made to produce all the effects of faradism. In large hospitals, where many patients have to be treated, several may be placed on the same insulated platform and be treated at the same time, as is done in La Salpêtrière.

Some interesting observations, showing the effects of static electricity, have been published by Blanc-Fontenelle. Ten cases in all were treated, three or four being placed on the insulated stool at once. In four cases of anæsthesia (three of hemianæsthesia and one of complete anæsthesia) electrization quickly restored the sensibility, which, however, tended to disappear again. In the case of complete anæsthesia sensibility only returned to one side. After each sitting the anæsthesia in three cases disappeared, and then returned again after various intervals. The same phenomenon occurred after each sitting, and finally the sensibility was completely restored. Of two cases of amyosthenia (paresis) one sitting was sufficient to restore the strength of the affected hand, as measured by the dynamometer. Of four cases exhibiting hystero-genetic zones, pressure upon which readily produced convulsive attacks, in all but one these zones disappeared under static electrization, so that pressure failed to cause an attack. The author states that static electrization diminishes the disposition to contracture and sometimes makes it disappear. On the other hand, Eulenburg, in his table of cases[1] (embracing a variety of affections treated by static electricity) records seven cases of hysteria, none of which were cured.

This is a fair illustration of the varying results obtained in the treatment of hysteria by electricity, as well as by every other method. Even the rest-and-seclusion treatment of Weir Mitchell must testify to a similar record. The fact is—and it is a fact that must be recognized—that in no disease does the personal equation of the physician play so important a part as in hysteria. Some physicians, men of character and strong personality, will succeed with a given mode of treatment where others fail. No greater compliment can be paid to the force of character of certain physicians than that they have been able to apply with success the Weir-Mitchell treatment of hysteria and neurasthenia where others have tried it in vain. They are probably unconscious how much their own personality has to do with their success, rather than the treatment *per se.* The rest-and-seclusion cure is not a method that will succeed in any one's hand as a drug or the surgeon's knife will succeed in other diseases. It is a method that is peculiarly fitted for him who has natural gifts which will enable him to make use of it. In a great measure it is likewise with electrization. Certain persons will obtain successful results by electrization for hysteria, while others will not. The proneness of hysterics to respond to suggestion, conscious or unconscious, makes this easily intelligible. Unconscious suggestion on the part of a physician

[1] Deut. med. Wochenschrift, March 1, 1889.

is as important an element as that which may be given deliberately, and must be guarded against. The effect of electricity, tonics, rest, and everything else may be undone by thoughtlessness on the part of the physician, as well as of the nurse and friends. Many a patient has been kept an invalid for months, if not years, by this subtle influence. The mere tacit assumption of the physician that nothing can be done to improve the patient's condition, or the sympathy of friends who bewail the patient's sufferings, may be sufficient. In some cases nothing has a more injurious effect than forbidding the patient to do certain things for fear of increasing the symptoms. Acts which bring on discomfort are apt to be interdicted, instead of the patient being encouraged to persist in them until their ill-effect disappears. In this way hysterical-habit neuroses are created which are difficult to break up. The power of the will to control the body, as well as all automatic processes of inhibition, become lost. The patient must then gradually learn to regain this.

On the other hand, in hysteria unconscious suggestion may work for good, as when the physician, believing firmly in some simple remedy, unwittingly gives a powerful suggestion of cure. The already-cited examples of metallo-therapy and magnets, to which may be added such quackery as Perkins's points, are illustrations. Care, then, must be taken not to undo the good gained with electrization by injudicious management of the patient. The patient must be encouraged to hold every little that is gained, and must be convinced that she can if she will. I do not speak of adjuvant treatment, such as rest, seclusion, and forced feeding, as they are not germane to this subject, and it is to be understood that they will be employed when necessary.

Electrization may be applied *generally or locally.* It is usually desirable to tone up the general system, with the view of removing the general hysteric "diathesis," upon which, in many cases, the local manifestations depend. As long as this continues, there will be relapses, or the local outburst is liable to take on some other form. Besides the usual therapeutic methods for this purpose, general electrization, either in the form of faradization or franklinism, is of service. Before and after the local application the patient may be given a thorough treatment of this kind. If static electricity is used, the head douche, followed by mild sparks or the breeze, to the remainder of the body should be given for twenty minutes to half an hour. This will usually be found to have a refreshing and invigorating effect.

Locally, electrization is applied to remove individual symptoms. The paralyzed, anæsthetic, or painful part is then treated directly. When cerebral symptoms are present, they are to be treated as described under "Psychoses." When the hysteria is strictly local, whether as a paralysis or a sensory neurosis, a few applications of electricity to the seat of the trouble oftentimes dispel it entirely. In such cases the hysterical affection is apt to be merely the residue of some other foregoing affection, or

a complication of another co-existent but distinct disease. Where, however, there is present a deep hysterical diathesis which is the basis of the local defects, the latter have a tendency to return after they have been removed, as has just been pointed out, or else the hysteria shows itself in some other form. Therefore a cure cannot be established without the restoration of mind and body, as a whole, to a normal, healthy condition. Meanwhile, it is advisable to remove, if possible, the local stigmata, as thereby the cure of the general diathesis is facilitated. The complete cure of grand hysteria is pronounced by some to be impossible. This is unquestionably going too far, though it may be difficult to effect a complete cure, for, as Gowers says, many hysterics have been restored sufficiently to health to lead useful lives.

The manifestations of hysteria are so numerous that it is impracticable and hardly necessary to consider the treatment of each. A few only of the more important will be here referred to.

Hystero-Epilepsy.—It is stated that faradism will cut short and prevent an attack. One electrode may be placed on the spine, the other to the sole of the feet, or one on the back of the neck and the other on the epigastrium, as recommended by Didier, who considers faradism one of the best means at our disposal. Charcot recommends galvanism to the head for the same purpose. The current may be made and broken several times, due care being used. Richet and Roux succeeded in cutting short attacks by this method. Trouvé used a strong galvanic current (40 to 50 cells), with sudden reversals, with similar effect. Static electrization is used at La Salpêtrière for the purpose of curing this form of hysteria. Several patients are placed upon the insulated stool at once, and charged simultaneously. The effects are said to be favorable, and to influence the general habit, as well as to cut short an attack. Charcot states that, after static electrization, pressure on the hystero-genetic zones ceases to produce an attack. The results of Blanc-Fontenelle have just been mentioned. He found that, whereas, in certain cases, the lightest touch to these zones produced a convulsive attack, after the application of static electricity the strongest pressure failed to do so. When electrization fails, resort must be had to one of the other numerous methods of treatment.

Anæsthesia.—The faradic and static forms are the most serviceable. There are several ways of using faradism. The wire brush is the most effective electrode, as it causes the most intense stimulation. The whole anæsthetic area may be brought under its influence, according to the method of Rumpff, who has advocated the electrization of large surfaces, with the idea of acting on the central circulation, which, as he has shown, is modified by such peripheral stimulation. (Page K–28.) Another method is to concentrate the stimulation on a circumscribed region, according to the method advocated by Vulpian, who found that faradization of the skin of the forearm on the anæsthetic side caused a return of the sensi-

bility not only to the part faradized, but over the whole corresponding part of the body. There is no reason to suppose, however, that there is any specific relation between this portion of the skin and the sensory centres, as faradization of other regions, and even of sound portions of the body, will accomplish the same result.

It is an interesting fact, however, that strong, localized faradization will remove not only anæsthesia of the part, but of distant portions of the body. How much of this effect is due to changes in the central circulation, how much to reflex nervous processes independent of the circulation, and how much to psychical influences, it is impossible to say. Probably it is due at one time to one of these factors, and at one time to another, or to all three.

Static electricity is probably equally successful in restoring sensibility. It is to be applied in the usual way. In France *franklinism* is applied as a powerful æsthesio-genetic agent. Charcot, who was among the first to study its action, found that anæsthesia could be transferred from one side of the body to the other, and finally dispersed for good. Vigouroux has also had favorable results. Although there is a tendency for the anæsthesia to return, yet, even when this is the case, a patient can be kept nearly free from anæsthesia by repeated applications,—not an inconsiderable aid to a final cure.

Galvanism is also not without influence. Whatever form of electrization is adopted, it is, as a rule, more effective when powerful currents or strong sparks are used.

As has already been said, there is a strong tendency for hysterical anæsthesiæ to return. In such cases the general "diathesis" must be treated on commonly-accepted principles. Electrization should, however, be persisted in, and the anæsthesia removed as often as it returns. In many cases it will be found that, after a number of sittings, it will disappear for good. The practitioner must always be prepared to meet obstinate cases, upon which the effect of electrization will be absolutely *nil.* Among them will be many traumatic cases, which will positively refuse to get well as long as litigation and other sources of auto-suggestion persist.

Paralysis.—The behavior of paralysis to electrization varies greatly in individual cases, as has already been said, and it is difficult to predict beforehand the result. Some cases are cured rapidly; some slowly, after repeated sittings; some are uninfluenced. It is always worth trying.

Aphonia may often be removed at a single sitting. On the other hand, as is likewise the case when a cure is effected by other means, there is a tendency for it to return. One reason for this is that it is really but the expression of an hysterical state, and as long as this latter persists the aphonia is liable to appear. In one sense it is not a true paralysis, but is rather an inability to use the laryngeal muscles for a particular purpose,—phonation,—while the acts of coughing, and some-

times singing, which equally depend on the action of the afflicted muscles, can be performed. In other words, the power of contraction *per se* is not lost. The affection more properly belongs to or approximates another type,—that of ideational paralysis,—which will be presently spoken of.

For the treatment of this paralysis faradization is the usual method. Both poles may be placed externally on the larynx, or, if this is not sufficient, a laryngeal electrode should be inserted within the larynx and the other placed externally. More technical skill is required for this. Weir Mitchell recommends instructing the patient to take a deep inspiration before speaking, when there is a lack of co-ordination between the laryngeal and respiratory muscles. By this means the patient is helped to once more resume volitional control over the necessary co-ordinated movements.

There is another form of paralysis, which was first described by Russell Reynolds,[1] and which, although not identical with, is allied to that due to hysteria; it may be designated as

Ideational Paralysis.—Paralysis is not the only form in which this neurosis appears. Other disorders, such as spasm, pain, paræsthesia, and various sensory disturbances often occur. Sometimes various minor psychical symptoms are met with, and give the impression of hypochondriasis or some form of hysteria. The pathology is always the same, and what is true of paralysis is true of the other forms of this disorder. Properly speaking, a paralysis of this kind is not true hysteria; but it is allied to it, and in practice it usually is diagnosed as of this nature. It will, therefore, not be out of place to consider it here. It is fairly common, but ordinarily its real nature is overlooked, so that its existence is not as well recognized as it should be. It requires some acumen on the part of the physician to distinguish it from true hysteria. The practical importance of doing so is that, unlike hysteria, it is readily curable, and electrical treatment is one of the most effective methods. If not recognized, it may persist for years. Its pathology seems to consist in the idea taking possession of the patient's mind that a given set of muscles cannot be used. All volitional control over these muscles has been given up by the patient. This surrender seems as if made voluntarily, instead of involuntarily, as in the case of hysteria, and often has its origin in some antecedent condition, such as traumatism. In such cases the patient's idea is a logical deduction from such real conditions, or has originated in some way by auto-suggestion. In every other respect the subject may be without a trace of hysteria,—in fact, may be perfectly normal in every way. Careful examination will fail to reveal other symptoms of hysteria, such as implication of the special senses, anæsthesia, emotionability, contractions, etc. Nor is there a tendency for a paralysis of this nature to return, unless the exciting cause persists, or

[1] British Medical Journal, November 6, 1869.

unless it occurs in a person who has the hysterical diathesis. In the latter case it may be impossible to distinguish it from true hysteria. Russell Reynolds, in his original description of the affection, in summing up its chief characteristics, says " (1) that some of the most serious disorders of the nervous system, such as paralysis, spasm, pain, and otherwise allied sensations, may depend upon a morbid condition of emotion, of idea and emotion, or of idea alone; (2) that such symptoms often exist for a long time, appearing as complicated diseases of the brain and spinal cord; (3) that they resist many different kinds of treatment, being alike unmoved by sedatives or irritants, by attention or neglect, but that they disappear on the removal of the erroneous idea; (4) that they occur independently of anything that can be called either insanity of mind, hysteria, hypochondriasis, or malingering; (5) that they are often, but not constantly, associated with some bodily weakness or general debility; (6) that they sometimes associate themselves with distinct and definite diseases of the nervous centres, so that it becomes very important to know how much of a given case is due to organic lesion and how much to morbid ideation; (7) that it is possible to make a diagnosis in regard to them in many instances; and (8) that the principles upon which their treatment should be conducted are simple and their application marvelously successful.

One peculiarity of this paralysis from idea is, that the subject can often use the affected muscles for one purpose, though not for another. There is a paralysis of movements, rather than of the muscles themselves. These movements are those involved in the particular idea that is at fault. For example, a subject while lying down may be able to move his legs in all directions, or to rise to a sitting position, although he may not be able to stand or to walk. The reason for this is apparent. This peculiarity was present in the following observation, which is a good illustration of the affection, particularly as the paralysis occurred under circumstances which gave every reason to suppose that we had to do with an uncomplicated focal injury to the spinal cord:—

Observation 1.—P. G. was originally admitted to the Boston City Hospital with fracture of the spine, causing paraplegia. After his discharge he was admitted to the department for nervous diseases. At this time his condition was as follows: He was only able to walk by the aid of crutches. He stood with difficulty, with his feet wide apart, and walked with hesitation and uncertainty unless supported. He stood with his knees slightly bent and his back thrown back, in a position difficult to describe. He complained of great pain in the lower part of his spine and buttock on sitting down, and therefore refused to sit while waiting his turn to be examined. There was apparently great weakness of the glutei muscles and of the extensors of the leg, for he had difficulty in raising himself to an erect posture after being made to bend over, and he carried himself with the centre of gravity thrown backward, so as to relieve these muscles. There was also difficulty in extending his lower leg.

The details of the examination of the reflexes, sensations, muscles, etc., are omitted here for brevity. At first the diagnosis was paralysis of the extensors of the leg and of the glutei muscles from injury to the cauda equina. This at first seemed clear, but when the patient was made io lie down, and the muscles were tested in that position, it was a matter

of surprise to find that he had complete control of both the extensor and flexor muscles of the thigh, as well as of the lower leg. The case was a puzzling one, and it was difficult to come to a conclusion in regard to the distribution of the paralysis.

He was examined twice with great care, with a view to studying the subject of spinal localization in the light of this case. As there was also marked toe- and foot- drop on both sides, with atrophy and loss of electrical reaction of the corresponding muscles, it was certain that there was present some serious injury to the nerves or cord ; but it was difficult to localize it, or account for the peculiar distribution of the paralysis.

At his next visit it was not possible to examine him, owing to lack of time ; but that he might not be disappointed at what might appear to be neglect, I directed that he should be given static electricity, and instructed to return for further examination.

After a few moments I went into the adjoining room, where he was being treated, and watched the process. Then, of a sudden, a sort of inspiration came to me, and in a commanding tone I ordered him to get off the chair and walk, assuring him that he was perfectly well and could do so. He looked at me incredulously, as if I were not in earnest. After some hesitation he obeyed. To his surprise, as well as ours,—for till this moment we had not suspected the true nature of his malady,—he got off the chair and walked around the room, incommoded only by a certain amount of foot-drop which he did not notice. Nothing was more ludicrous than to see him, as he walked about, staring at us in astonishment, his eyes as "big as saucers."

Owing to the foot-drop, he raised his feet high in walking. He was told to leave his crutches and go home. He did so, and walked all the way to his residence,—a distance of several miles. At his next visit, two days later, he still retained command of the formerly paralyzed muscles. He, naturally, seemed to think a miracle had been performed.

In this case, then, there had been a combination of paralysis of the feet and toes, from organic injury to the cauda equina, with a large amount of functional paralysis involving the trunk- and thigh- muscles. The latter was dependent on idea. The origin of this ideational paralysis could be traced to a true, but temporary, paralysis of the same muscles following fracture of the spine, but which had cleared up. He was left, however, by the accident, under the dominant idea that he could not use his legs for certain purposes, and as long as this idea persisted he could not do so.

The following observation may also be cited :—

A lady was attacked with an ulnar neuritis while convalescing from the "grip." She suffered from intense pain, which had nearly subsided when she came under my personal observation, about six months from the beginning of the attack. At that time there was marked paralysis of the hand, the use of which she had for the most part given up. She could not flex the fingers into the palm of the hand. There was tenderness of the nerves and skin, pain, and slight glossy skin, but there was no atrophy of the muscles or alteration in the electrical reaction. The diagnosis was mild neuritis, complicated by ideational paralysis. The latter was concluded as the result of cross-examination and a critical analysis of her history, which would be too lengthy to detail here. She was assured that the paralysis could be cured, but no opinion given regarding the pain, which was due to the neuritis. After the first electrization there was an *immediate* return of power to her hand. After a few sittings there was only a slight weakness, if any, left. The exact amount of strength could not be measured, on account of the tenderness which persisted. This also greatly improved under treatment, so that, when discharged, her disability was only slight from pain.

The course of events in this case was evidently as follows : In consequence of neuritis the patient suffers great pain, possibly some muscular weakness, and gives up all use of the hand. At first the patient cannot use the hand ; later, without her being aware of it, the neuritis disappears, but the patient remains still under the impression that she cannot use it. She cannot will to use it, because of the strength of this idea. It requires a strong stimulus to enable her to regain power of the muscles. This was afforded by the treatment.

In the experience of the writer, most cases of ideational paralysis

have their origin either in some injury to a part suspending function or in some previous acute disease having the same effect. More rarely, in impressionable subjects, the affection can be traced to mimicry, or the effect of suggestion inspired by the presence of another person afflicted with a real disease. If litigation is in progress, no treatment will have any effect.

There are other methods besides electrization for curing this affection; for example, gradual education of the patient to resume control of the paralyzed muscles. It is not necessary, however, to go into these here. The method of using electricity is the same as for other forms of paralysis. The muscles must be made to contract energetically by powerful currents. It is often serviceable to induce the patient to make efforts to contract the muscles voluntarily in unison with the electrical contractions. All the muscles of the paralyzed part should be treated. Faradism is the most effective, but galvanism and franklinism can be used.

Hysterical *paraplegia* is generally regarded as very obstinate to electrical treatment. *Monoplegia* and *hemiplegia*, in the writer's experience, are also apt to be rebellious, but sometimes the result is satisfactory.

Contractures are not, as a rule, benefited by electricity. Cases of cure are, however, reported.

Neuralgia is more readily controlled by electricity than any of the hysterical stigmata. In fact, there is no method of treating this symptom that compares with electricity. Often pain will disappear like magic during a sitting. It is true that frequently it will return, but this is no valid argument against its usefulness. Pain, in itself, unlike anæsthesia and paralysis, is so great a source of suffering that anything that will suppress it even temporarily will be welcomed. In cases of some chronicity, especially when the hysterical symptoms are a complication of some other disease, the patient may be kept comfortable for months by daily electrization, when otherwise resort must be had to drugs, with all the attendant disadvantages. In a case, for example, of traumatic neuritis, with marked histerical neuralgia as an accompaniment, the suffering was made endurable for a year, pending the settlement of the litigation. This relief was given not only to the hysterical neuralgia, but to that from the neuritis. In this case the pain was at times excruciating.

In a case of neurasthenic hysteria now under treatment, in which the principal suffering was produced by neuralgiform sensations in the head of great intensity, which had practically disabled the patient for five years, and confined her to her bed for three years, the patient has been kept fairly comfortable while she is undergoing the Weir-Mitchell treatment, and has been enabled to make efforts which otherwise would have culminated in severe attacks of pain and prostration. The result bids fair to be a success.

Spinal tenderness is often completely controlled by electrization, as

well as many of those pains in the back and legs supposed to be due to uterine difficulty. Static electricity is, on the whole, the most efficient form, as it is the most convenient. In the absence of an influence machine, the galvanic or faradic currents may be used. Sometimes one of these is the more efficient, and sometimes the other. Care must be taken, with sensitive subjects, not to use too strong currents at first. With each sitting the current may be increased, until finally a strong one can be borne. A strong current is more effective than a mild one, when the pain is intense. With timid subjects the galvanic current has the advantage of being less alarming. Whichever variety be used, the current or sparks, should be applied directly to the seat of the pain, and at each sitting electrization should be persevered in until some degree of relief is experienced. It will be very rare that the patient does not admit at least a diminution of the pain, if not total cessation. If the pain return the interval of freedom will probably be prolonged, and the pain will be rendered less intense by each subsequent sitting.

When using the faradic and galvanic currents one electrode should be allowed to rest on an indifferent part of the body, while the other is gently rubbed over the painful part without being removed from the skin. The current, at first mild, should be gradually increased until it becomes as strong as can be borne. With the galvanic current it is generally considered that the positive pole has a more anodyne effect than the negative. There is no harm in following this rule, though there is some reason to doubt the fact on which it is based. It is well to let the active electrode rest for a few moments over painful spots, until the current becomes unbearable.

NEURASTHENIA.

(PSEUDO-NEURASTHENIA.)

The opinion is generally entertained, by those who have had a large experience with electro-therapeutics, that many cases of neurasthenia are very favorably influenced by electrization (Beard, Rockwell, Erb, Rumpf, Fischer, Möbius, Arndt, Eulenberg, and others). On the other hand, the general practitioner, who is less familiar with this mode of treatment, either completely ignores these claims or exhibits an extremely skeptical attitude of mind regarding them. There must be some truth—perhaps some exaggeration—in each of these conflicting views. Between the extremes of confirmed faith and utter indifference there must be a safe middle ground on which we can stand. It may be stated at the outset that the effect of electrical treatment on that large group of diseases known as neurasthenia gives very varying results. For this reason it is impossible to make a general statement of its value which is applicable to individual cases. To appreciate this fact, it will be well to consider in a brief way the nature of the disease with which we have to deal.

The pathology of neurasthenia is obscure, but whatever be its nature, whether it be an autocthonous poisoning of the nervous system, as some would have us believe, or whether it be exhaustion of the nerve-elements, after the manner of the changes which have been shown by Hodge, in his experiments on birds and bees, to follow prolonged use, or other molecular changes such as would be produced by inanition, its symptoms and the laws of their development must be studied by themselves as clinical phenomena for purposes of intelligent treatment; just as in physical science the laws of electricity must be studied and formulated in the absence of an exact knowledge of the nature of electricity itself. And just as the fluid hypothesis of electricity was convenient for the time being for practical purposes, so it is desirable to have a working hypothesis of the nature of neurasthenia, as a basis for clinical study and treatment. That of exhaustion is the most convenient, as it contains no assumption of the nature of the finer changes that may be involved in the morbid process.

Adopting, then, this hypothesis for the purposes of this discussion, we should expect, on theoretical grounds, that in the practical handling of this disease we should have to do with a great variety of symptom-pictures, many of which would present very little external resemblance to one another. As the nervous system is made up of segments, each of which, though connected with the rest, is yet more or less isolated and capable of acting as an independent automatic centre, we should expect that any one of these segments might become exhausted by disease without the implication of distant or neighboring parts. It might be anticipated that, in this way, a variety of symptom-pictures would be produced which would have little external resemblance to one another, notwithstanding the fact that nerve exhaustion would be the physical basis of each. And, in truth, practical experience has shown that what is thus at first sight presumably true, is, in reality, the case. Clinical experience teaches that neurasthenia, at one time, may be expressed by a variety of more or less compact, localized symptoms, indicative of exhaustion of comparatively limited portions of the cerebro-spinal system, while at other times the exhaustion may be more disseminated, and include a very large part, if not the whole, of this same system. Neurasthenia may be expressed, for example, by any one, or by a combination of several or all of the following groups of symptoms, according to the part affected: Cerebral symptoms, indicative of mental weakness, fixed ideas, incapacity for work, etc.; headache, vertigo, nausea, asthenopia; cardiac disturbances; vasomotor changes; localized pains in the spine, limbs, abdomen, loins, sacrum, etc.; gastric disturbances, such as dyspepsia, flatulence, etc.; uterine and ovarian pains and other symptoms referable to the reproductive organs; muscular weakness, especially of the legs; disturbances of the sensibility (such as formication), subjective numbness, faintness and sense of exhaustion produced by

slight exertion; inanition and physical degeneration, and so on. This, of course, is only an incomplete classification of the possible symptoms. When neurasthenia is more or less generalized, all these disturbances of function may be included in the picture, in which case, of course, the exhaustion will be more profound. The degree of localization, on the other hand, may be from an almost isolated phenomenon, due to the limitation of the process to one or more nervous segments, up to almost general exhaustion. Where, however, the nervous exhaustion is limited in its extent, it nevertheless almost always happens that symptoms indicative of the implication of other parts, distant or neighboring, are included in the clinical picture, because of the physiological association between all parts of the nervous system. Experience shows that, even when exhaustion, as a pathological process, is limited to special segments of the brain or spinal cord, the disturbances of function observed point to the implication of more remote centres by an abnormal diffusion of normal nervous stimuli; or, if the term be preferred, by reflex influence. From this it will be understood that disturbances of function do not always indicate exhaustion of the nerve-centres as a physical basis; or, putting this truth in more general language, the *hypothetical anatomical exhaustion of the nerve-centres is not co-extensive with the disturbances of function* (*distribution of symptoms*). In fact, the disturbances of function have a much wider distribution than the exhaustive process, and the phenomena presented by the disturbances of associated, but healthy, centres may be so extensive as to overweigh and obscure that of the primarily diseased centres. In such cases the disability will be occasioned almost entirely by the secondary disturbances of associated parts of the cerebro-spinal axis, while the diseased and exhausted focus will be of secondary consequence.

Another element, at least, in the production of these secondary disturbances, and one which profoundly affects the symptom-picture, is the deficient inhibition of lower centres by higher centres. When the higher centres are exhausted, they cease to hold the lower centres in check. The latter go on working of their own will, without heed to the proper regulation of the nervous household. "When the cat's away, the mice will play." Hughlings-Jackson, in his able article on the evolution and involution of the nervous system, has maintained with great force the division of the nervous system into three levels of evolution,—the lowest (spinal cord and medulla), middle (mid-brain), and highest (frontal lobes.) All parts of the body are represented at each level. In disease, according to the views of this author, there is a dissolution of the nervous system in a reverse order,—from the highest to the lowest centres. In disease—and this is a point of great practical importance, and one which has been frequently pointed out by Hughlings-Jackson—there are two sets of symptoms,—one positive and one negative. The negative symptoms are those due to the destructive action of

disease. The positive are those due to the normal working of the remaining unimpaired centres, usually of lower levels. When an aphasic swears, for example, his profanity is due to the normal physiological working of the only remaining uninjured portion of his speech-centre; the deliriums of fever or hallucinations of insanity are the expressions of the physiological workings of the remaining levels of consciousness, etc. This law, which Hughlings-Jackson has fortified with great force of argument and example, has special value in explaining many of the clinical phenomena of neurasthenia. The exhaustion of the highest centres gives rise to an inability on the part of the subject to perform certain mental and physical acts. But the lower and unexhausted centres act normally and physiologically, and give rise to phenomena which, because unusual, are regarded as pathological. The lower centres react in place of the higher or highest centres. If the latter were not exhausted, the lower would be inhibited, or quiescent. From this point of view, many of the symptoms of neurasthenia are really the expression of the normal or healthy centres, either from lack of inhibition or because of the exhaustion of the higher levels. They alone can functionate. Such functionating centres are not diseased, and the phenomena presented by their functionating are not to be taken as indicative of pathological processes located therein.

It is not the writer's intention to enter into a discussion of the pathology of neurasthenia; the object here is only to indicate the mechanism of the pathological process so far as is necessary to understand the conditions that must be met for purposes of treatment. The treatment cannot be intelligently undertaken unless the make-up of the symptom-picture of neurasthenia be understood. If these views be true, it becomes evident how impossible it is to make general statements of the efficacy of electricity, or any other agent or system of treatment that shall be applicable to all cases. We might predict from *a priori* considerations —in fact, we find it true—that electricity produces results in one class of cases of neurasthenia which are not obtained in another. When, for example, symptoms indicative of lack of inhibition or reflex irritation of associated centres predominate with only local exhaustion, the effect of electricity is likely to be more curative than when the opposite extreme is present, and when all the symptoms are due to a general exhaustion of the whole cerebro-spinal system, with imperfect nutrition and other forms of physical degeneration. In the latter case you could not expect to obtain curative results without first building up the body with food and improving the nutrition and increasing the amount of blood. In fact, it is in this last class of cases—in which inanition and anæmia exist, with their own train of symptoms—that the rest-cure of Weir Mitchell, with overfeeding, becomes necessary. But in these cases electricity is of use as a palliative. Many of the more distressing symptoms can be relieved and kept in abeyance by electrical treatment.

Insomnia and painful spine, headache, and similar disturbances are often kept under by means of electricity, and constant drugging is dispensed with.

The effect of electricity in neurasthenia, then, may be said to be (*a*) palliative and (*b*) curative. In most cases the palliative effect is obtained rather than the curative, but, nevertheless, there is a certain class of neurasthenics who may be said to be cured with electricity. And here another element may be referred to as influencing the effect of the treatment,—namely, the hysterical element. Hysteria, in one form or another, is very often associated with neurasthenia, just as, in hysteria, neurasthenia is superadded frequently as an additional factor. It is not often that we obtain a pure type of nervous debility. From a practical point of view, we may almost make a third group of cases, classified as hystero-neurasthenia or neurasthenic hysteria, according as the hysterical or neurasthenic symptoms predominate. Electrical treatment of these cases effects results which cannot always be obtained in the pure types. It may be that the hysterical symptoms will disappear, leaving a pure neurasthenia, or the asthenic symptoms may clear up, leaving the hysterical only behind.

The great difficulty in practice is to determine what class of cases is most likely to be benefited and what class not. Speaking generally, it may be said that the most favorable cases are those in which the nervous exhaustion is well localized and the symptoms are for the most part due either to defective inhibition or to secondary reflex processes. The effect of treatment is also likely to be more favorable when the case has been of short duration, the physical condition of the body is good, and the nutrition is not impaired. The least favorable cases are those with neurotic antecedents of long duration, and in which, from the long continuance of the neurasthenic conditions, the nutrition of the body has become impaired and the disturbances of function have existed for so long a time that they have become engrafted almost as automatic, independent processes. There are neurasthenics who may almost be said to be born neurasthenic, to live neurasthenic, and die neurasthenic. Such may be improved by this or that treatment, or they may have their lives made fairly tolerable by careful regulation of habits, and be relieved from time to time of any prominent symptom. Electricity will help these from time to time, it may relieve them from this or that thing from which they suffer, but it will not cure them. Such persons may be said to go through life like an old doctor's rickety buggy,—always worn out, always rattling and creaking, but never completely breaking down so as not to go at all. Another less severe type of cases may be decidedly benefited, if not cured, by electricity. This agent is a great help in their treatment; it palliates; it will relieve many of the distressing symptoms, and thus ward off the effect which constant suffering has in retarding recovery; while good food, fresh air, and exercise do the rest

and effect a cure. In the more local forms of neurasthenia electricity often produces the most brilliant results. Sometimes even a few sittings will not only dissipate most distressing symptoms seemingly like magic, but will do so permanently, and enable the patient to be discharged cured. Such cases every one who has had a large experience in electrical treatment has seen and can testify to. Although there is much difference of opinion regarding the efficacy of electricity in the treatment of affections of this kind, this difference depends very largely on the difference in the views entertained regarding the pathology and the consequent diagnosis of such cases.

Probably no two persons would agree exactly as to what shall be included under and what shall be excluded from neurasthenia. With many neurasthenia is a general cloak to cover almost any functional disturbance; with others it is limited to a comparatively small class of cases. The tendency at present is to expand the term and make of it a sort of general omnibus, into which everything that is not organic, or does not belong to a special type, shall be dumped. It seems as if, like an omnibus, there is always room for one more disease. This tendency, it is needless to say, has already gone too far. It is time that a serious attempt should be made to differentiate the various types of functional diseases of this sort from one another, and to classify them according to their pathology. The writer's views regarding what class of cases are likely to be benefited and what are not will, perhaps, be best explained by a few illustrative cases:—

Cases Not Benefited. Observation 1.—Woman, about 50 years of age; in opulent circumstances. Descended from neurotic family, has always been neurotic from childhood; never has been strong; as a girl was subjected to a great deal of nervous strain, and, being of almost a morbidly conscientious temperament, has always found it difficult to reconcile her actions with her ideas of duty. Great tendency to dwell on the moral side of any contemplated act. Nutrition is poor; underfed; rather anæmic. Breaks down under almost any strain; suffers from sick-headache; tender spine; nausea; functional ataxia; vasomotor phenomena; heat and flushes; cold hands and feet; palpitation; general muscular weakness; hemiparæsthesia and anæsthesia (subjective only) of left side. Any psychical shock, such as a rude word or personal controversy, will bring on a whole series of these symptoms. Cannot walk without becoming greatly exhausted and other symptoms following. Auto-suggestion marked and easily recognized. This can be taken advantage of for treatment. Patient is intellectual, unusually intelligent, and cultured. As soon as her condition is improved she breaks down under some strain which would not affect another person. Attempt was made to treat her by electricity, but, although a very slight charge of the static electricity was used, a series of symptoms developed which, it was later ascertained, were identical with those supposed to be caused in her by a thunder-storm. Patient confessed she had prejudices against electricity and expected just such symptoms would come on.

Observation 2.—Woman, about 30 years of age; in well-to-do circumstances. Neurotic from her childhood. Had quite frequently fallen into hysterical trances. Symptoms: General lack of strength, palpitation, headache, dyspepsia, vasomotor disturbances, poor nutrition. Physical exertion causes great prostration, vasomotor and other disturbances. Treated by the rest-cure with great gain in weight; nutrition improved, and she was much better generally. Broke down again immediately after attempting to return to ordinary

life. Electricity not only failed to relieve the symptoms, but, as in Observation 1, produced symptoms said to be similar to those produced by a thunder-storm. The reflex irritability was extreme: almost any form of irritation, whether physical or mental, produced distressing symptoms.

Observation 3.—Young woman, married, 22 or 23 years of age, with neurotic antecedents. Health poor generally; dyspepsia; unable to eat more than the slightest quantity of food; irritability and torpid action of the bowels alternating with each other; great physical fatigue; very marked symptoms of pseudo-angina pectoris, which always caused much alarm. The fright from these attacks induced, in turn, numerous association symptoms. The cardiac attacks were brought on by physical exhaustion, mental irritation, and indigestion. In consequence of last, patient even refused to put water into her stomach. Under the Weir-Mitchell treatment patient was taught to take and digest large quantities of food, and her physical condition improved generally; but she did not regain strength, and immediately broke down again on her restoration to her former habits of life. Electrical treatment in this case failed to accomplish any beneficial results.

Cases Curable by Electricity. Observation 1.—Mrs. E., about 35 years old; naturally a strong, healthy woman. Well up to one year ago. Has led a fast life. Previous to breaking down, one year ago, had been drinking hard for two years. Finding herself becoming used up, broke off drinking entirely. About that time began to suffer from the same set of symptoms she has now; has been better off and on. Patient, when first seen, was in bed, where she had been for about ten days. Complained of palpitation, which she described as due to some supposed trouble of the heart, for which she had been treated. Also had "nervous feelings," the latter said to resemble the feeling from a faradic battery "that went all over her." These symptoms were very disagreeable, and alarmed her. Complained also of muscular weakness, "goneness," marked sleeplessness, general numbness, and dizziness; unable to walk but a very short distance, because of prostration. Physical tire brought on attacks of the above symptoms. Patient was up late at night and obtained very little rest and sleep. Had been treated during the past year by various doctors. One had treated her for a long while for heart disease. Physical examination showed her to be a strong, healthy-looking woman, good color, heart normal, no objective signs. Told to get up next day and come to the office in a carriage for electricity. Patient considered her condition so serious that she was arranging to break up her household and go into the country. Next day, treated by static electricity. The effect of the first sitting was beneficial. She at once felt better, refreshed, and relieved of various symptoms. Two days later patient reported herself as greatly improved; symptoms had largely disappeared, and she slept well. Static electricity was re-applied with same beneficial effect. After this, patient so well that treatment was discontinued, and she gave up her plan of going into the country.

Observation 2.—Mrs. E., 35 years old; married; has the appearance of being a strong, healthy person, with good color, but states that she never had been strong and was always easily tired. Eleven years ago, while going down front steps, slipped and fell, striking her back; fainted. Ever since has had a pain in the middle of her spine. This pain has increased of late, until now it is difficult for her to do any work. Is wearing a spinal corset for this, and is supposed to have some sort of lateral curvature. Has had numbness of the whole left side, off and on, for eleven years. These symptoms antedate the fall. Feels tired all the time; lack of energy; little things worry her; has sleepy spells during the day-time, when she lies down and sleeps soundly; almost impossible to keep awake at such times; walking, housework, and driving tire her and make her back ache. This pain is "terrible"; feels dizzy at times, as if falling backward; certain positions in bed make her feel as if turning a somersault backward; nausea at times; has "gone," faint feelings. Patient says that sometimes, on waking from these sleepy spells, she knows what is going on around her, but cannot speak. Mother and maternal grandfather are said to have had "fits" (?) (no spasms). Number of others died of consumption. Physical examination: No objective symptoms, except great tenderness of the spine. Treatment: Patient ordered to take off the spinal corset, and static electricity given, at first every other day, then at longer intervals. Eight sittings were given in all. The effect of electricity at each sitting was to dispel

any unpleasant symptoms present, such as tenderness of the spine, headache, and numbness, and patient declared herself as feeling better and stronger after each application. At first symptoms returned after a number of hours, but in less intense degree. After eight sittings patient reported herself as well; able to walk long distances, and feeling in good health.

There was evidently a strong hysterical element in this case; patient was plainly amenable to suggestion, auto- and extrinsic. The brilliant effect of the treatment in this case is enhanced when it is remembered that for several years the patient had been an invalid, practically unfit for any duties in life; could do little without great suffering, and had been under constant treatment. It should be said, though, that the effect of electrical treatment was supplemented by strong moral lectures and a hygienic regulation of her life.

Observation 3.—Mild neurasthenia following the "grip." Lady, 51 years of age; in affluent circumstances; of a neurotic temperament. Symptoms: General malaise; slight prostration and subjective numbness of left side, or hemiparæsthesia. Treatment: Galvanization of the spine; after each sitting patient felt much refreshed and symptoms were dissipated. Patient expressed herself as being greatly relieved by electricity; after a few sittings patient discharged, cured. This patient previously had suffered at different times from a similar group of symptoms, and has always been benefited by electricity. Besides dispelling the symptoms, electricity acted as a general tonic.

It may be objected that cases in which striking curative results of this kind are obtained by electrical treatment are not really true cases of neurasthenia; that they are some form of neurosis simulating, but not identical with, neurasthenia. The writer has himself often pondered over this question, and has often asked himself whether such cases should not rather be called pseudo-, or false, neurasthenia, and has frequently been tempted to make a separate classification of neuroses under this head. But the attempt to do so has been thwarted by the difficulty of precisely defining what should be called true neurasthenia. The symptom-pictures of many are so similar that they cannot be distinguished except by the results of treatment, and, therefore, the differential diagnosis would have to rest upon the therapeutic results. This, in itself, for obvious reasons, is a very dangerous ground upon which to base pathological distinctions. Many cases which have promptly responded to a special treatment other than electrization have persisted for years in a neurotic condition under continuous and varied treatment improperly applied. A counter-objection might also be raised to limiting the term "neurasthenia" to the severe forms, on the ground that many of them, such as those that have been described above as well-nigh incurable, are themselves not true neurasthenia, but are dependent upon some profound pathological processes in the nervous system, of the exact nature of which we are yet ignorant. Some of them are certainly due to developmental effects and to hereditary influences. The careful study of many cases seems to indicate that in certain individuals the normal evolutionary process in the nervous system ceases at an early age, and the process

of dissolution sets in. This dissolution process thus gives rise to positive and negative symptoms generally classed as neurasthenic. The pathology of such cases must be regarded as very distinct from those which, in the midst of robust, active health, temporarily break down, as the result of overwork and mental and physical strain. Furthermore, the separation of a distinct class of neuroses as pseudo-neurasthenia does not give us any deeper insight into the pathological processes, and we should remain just as ignorant as before of their true nature. As long as the pathology of both true and false neurasthenia is unknown, it is impossible to say how much there may or may not be that is common to the pathological processes underlying each. For the present, it would seem better to regard pseudo-, or mimetic, neurasthenia as a true neurasthenia of limited intensity and extent, but on which have become engrafted various associated processes, of which it is principally made up. These associated processes are not in themselves the expression of disease of their own centres, but rather of the physiological activity of nervous segments which have ceased to be controlled by the normal inhibitory inferences of higher centres. It is for this reason that the electrical treatment in such cases seems to present such magical results.

Special Modes of Treatment.—Speaking now more specifically of special modes of treatment by electricity, it may be laid down as a general rule that our aim must be, in all cases, to fight the individual symptoms. Headache, insomnia, spinal pain and tenderness, muscular weakness, each must be attacked by itself. Headache and insomnia are often overcome by the galvanization of the head, or by the static douche. Sometimes the one form of electricity is the more efficacious, and sometimes the other. Tenderness of the spine is, as a rule, relieved or dispelled by one or another of the different forms of electricity. It is not uncommon to see the symptoms disappear immediately, under the influence of electrization, and remain absent for hours. In this way the patient may obtain prolonged relief from constant suffering. The same may be said of lumbar, abdominal, and other pains. These symptoms, however, do tend to return, after intervals of greater or less extent,—as a rule, after some hours,—but on their return they will generally be found to be less severe, and, if the patient is improving, they will be observed, after each sitting, to be of less and less intensity, until finally they disappear altogether.

Mental symptoms, such as melancholia or depression, vertigo, inability to apply the mind, etc., are also frequently benefited. The hemiparæsthesia, as a rule, of the left side, so commonly met with in neurasthenics, is readily dissipated by electricity. As a general tonic, electricity at times acts in a very striking manner, and patients declare themselves feeling refreshed and invigorated. They walk better and seem to have more vigor.

Regarding the *choice* of electricity, it is impossible to lay down rules that shall govern us in all cases. Sometimes all three forms—galvanism, faradism, and franklinism—act equally well. Sometimes one form produces distinctly superior results. For cerebral symptoms, galvanization of the head is strongly recommended by some writers, the current being passed longitudinally, transversely, or diagonally. Löwenfeld advises that, when symptoms of congestion are present, the anode should be placed on the forehead and the cathode on the back of the neck. He bases these rules on experimental results that he obtained on rabbits.[1] Even, however, if the same electrical effects are produced in diseased conditions in man (and it is very doubtful if this is the case), our knowledge of congestion and anæmia of the brain is too chimerical to allow us to base treatment upon rules of this kind with any degree of confidence. It seems to the writer that the results of electrical treatment do not bear out the statements made by various German authors, who lay down minute rules regarding the direction of the current and the poles to be used to overcome this or that pathological condition supposed to be present. I have not been able to satisfy myself that the effects obtained depend on the direction of the current or the character of the exciting pole. It is true that different physiological subjective symptoms are produced, according as the current is passed transversely through the temples, or longitudinally from the forehead to the nape of the neck. But these symptoms are mostly only subjective, and there is not sufficient evidence that the influence upon pathological processes similarly varies. Our knowledge of the therapeutic effect of electricity, as of drugs, is entirely empirical, and we must be governed in our use of it by the clinical results obtained. Certain it is, however, that the application of the poles of a galvanic battery to the head is often followed by a relief of many mental symptoms. Patients say, after each application, that their heads feel clearer, that the depression has vanished, and the feeling of weight and pressure on the top of the head gone; and they look forward with pleasure to each application.

The strength of the galvanic current should be such that it can be borne without great discomfort. Many writers caution very strongly against the use of any but very mild currents to the brain. It seems to the writer that rather overcaution has been exhibited in this respect. It is true that patients have sometimes, under very strong currents, experienced very disagreeable symptoms, and have even fainted; but such symptoms are not in themselves dangerous, and, if the current is maintained within the limits of strength that will produce such symptoms, no danger need be apprehended. Some writers say that not more than 1 or 2 milliampères should be used; but a better rule is to be guided by the physiological effect experienced. It would seem best to increase the current gradually until the first signs of vertigo are experienced, and

[1] *Vide* p. K–34.

then decrease the current at once if the vertigo increase or persist in a disagreeable form. It is, however, true that few patients can take more than 4 or 5 milliampères without extremely disagreeable sensations, but, if more can be borne, it is well to take advantage of the fact.

Five or ten minutes are usually sufficient for a sitting. The application should be made daily, if the circumstances are such that it is possible; or, at least, this is desirable for the first week or two; later, three or four times a week would be ample. Excepting when very weak currents are employed to the head, it should be a cardinal rule never to break the current, or make it, while the electrodes are *in situ.* Shocks of this kind are liable to produce very disagreeable symptoms. The best method is gradually to increase the current after the electrodes have been placed upon the head at the spot desired, and then to move them about without removing them from contact with the skin. In galvanizing the spine it is best to place one electrode at the lumbar extremity and the other on the neck, and then, while holding one steady, to pass the other up and down the whole length of the spine, allowing it to dwell for a longer or shorter time upon tender points, according as the patient is able to bear it. A good plan is to keep one electrode on one of these points, and to persist in the spinal galvanization of the spine until the patient expresses feeling relieved of his symptoms. In fact, it is always well, in applying electricity, whether to the head or to the body, to persist until some degree of improvement, even if slight, is felt by the patient. Sometimes, when a distinctly stimulating effect is desired, it is beneficial to make and break the current while the electrodes are over the spine. The strength of the current should be as strong as can be borne without discomfort. It is not desirable to make the current painful or disagreeable. When spots are present particularly sensitive to the current, the electrodes need not be allowed to remain on them longer than can well be borne, but the current should be repeatedly applied to them until relief is felt.

Arndt recommends general galvanization in neurasthenia. He advises that, when it is desired to obtain a quieting effect, as in the first stage of neurasthenia, the positive pole should be applied centrally and the cathode peripherally. When the opposite, or stimulating, effect is desired, as in the second stage of the disease, the poles should be reversed,—*i.e.*, the negative should be placed centrally and the anode peripherally. Unfortunately, little confidence can be placed in a system based on supposed differences in the therapeutic action of the two poles or of direction of the current, and equally good results are obtained by those who disregard rules of this kind. Sufficient has already been said on this point. Eulenberg, Erb, and others also recommend galvanism, either general or local, in this disease.

General galvanism, which was brought into prominence by Beard and Rockwell, is done as follows: One electrode is placed upon the feet.

It should be large, so that it can be retained *in situ*, during the sitting, without discomfort. The other electrode is then passed successively over the different parts of the whole body,—the limbs, the back and the spine, the abdomen, the neck, and, lastly, the head. When a painful spot, or a part the seat of pain, is reached, the electrode should be allowed to rest upon it or repeatedly passed over it until some degree of relief is obtained. It is sometimes surprising to see how local symptoms may be dissipated in this way. Tender spine, for example, may be readily quieted for the time being, at least. When treating the limbs, it is desirable to make the muscles contract a few times through the motor points. The object sought is twofold,—the stimulation of the whole nervous system through the muscles, skin, and peripheral nerves, and the inhibition of morbid central nervous processes. Twenty minutes will be found sufficient for a sitting. Care must be taken not to use too strong a current, otherwise stimulation will become irritation, and general secondary nervous symptoms may develop, to the chagrin of the physician and the disappointment of the patient.

Electrization, in this disease particularly, may easily be overdone, and the physician will be unpleasantly surprised to find that, instead of benefiting his patient, he has made a bad matter worse. This is not true of all cases of neurasthenia, but only of a certain class. It is not possible to determine beforehand what cases belong to this class.

So-called central galvanization is another mode of applying the galvanic current. I cannot help regarding it as a refinement, without practical advantage over other methods. It consists in placing one electrode over the epigastrium (the negative, as recommended by Beard), and applying the other to the spine, head, and "sympathetic." The object is to concentrate in this way the action of the current on the central nervous system. It does not appear that the results accomplished by this mode of electrization are superior to those obtained by the other methods above described, or that the central nervous system is more directly acted upon. The brain is fully as well acted upon when both electrodes are placed upon the head, and the evidence is lacking that the spinal cord can be directly influenced by the current. Although clinical experience shows that electrization over the spine does have a therapeutic effect, this is probably due to reflex action. The same may be said of galvanism of the sympathetic, which de Watteville has shown to be a piece of imaginary therapeutics, as there is no reason to believe that the sympathetic is acted upon. He proposes the name "subaural galvanization," as the application of electricity to this region is believed to have a special effect in neuroses.

Faradism is also recommended by some writers. Arndt advises that the faradic current be used when an indirect stimulation of the nervous system is desired,—that is, through the skin. This author cautions against the use of too strong a current, or too frequent or too

extended applications of the same. In this he is quite right, though there are some cases which can be faradized without limit. General faradism, so highly spoken of by Beard, is also strongly recommended. The technique is the same as when using general galvanization.

Another method of using faradism is that advocated by Rumpf,—namely, the brushing of large surfaces with the faradic brush. This method is based on the experiments (already referred to) by Rumpf, Nothnagel, and others, who found that excitation of the skin was followed by contraction of the vessels of the brain and spinal cord. Rumpf claims to have obtained very favorable therapeutic results by this method.

Of late years *static electricity* has come more and more into use. The ease with which it can be applied—avoiding, as it does, the necessity of the removal of the clothing and the wetting of the body—makes it a particularly convenient form of electrization; and for this reason, when its effects are equally good, it will always be given the preference by the physician. In some forms of neurasthenia the effect of static electricity is particularly good,—fully equal and often superior to that of galvanism or faradism. In relieving insomnia, headache,—above all, mental depression and spinal tenderness,—the writer has obtained very favorable results with it. The different effects that can be produced, according as the spark, the douche or breeze, or simple insulation is employed, render it a very valuable therapeutic agent. It can be even converted into the dynamic variety, with effects similar to that of the faradic current. The static breeze, applied to the head, will sometimes relieve depression and headache like magic. Severe peripheral pains and the different neuralgias are very readily relieved by the spark. Even the pains of neuritis are often temporarily modified. One has to be careful, however, with sensitive patients, not to begin too violently with this form of electricity. Very sensitive patients often at first respond badly to static electricity when given strong, and for this reason it is often best with them to begin with the milder galvanic current, and later change to static electricity.

Electric baths remain to be spoken of. These have been strongly advocated by some writers. Electrization is certainly more general by this method than by any other, but whether it is more effective remains to be proved. Theoretically, there does not seem to be any reason why it should be, or even as effective. I have not myself had any experience with electric baths, and, therefore, cannot express an opinion on this point. It is probable that they appeal to the imagination, and, therefore, have a psychical influence. One advantage that this method has is, that it combines the effects of baths and electricity. Hot and cold baths, particularly the former, are often very soothing and refreshing in neurasthenia. I have known them to be very useful in this respect, and, when combined with electricity, I can imagine the effect to be very

pleasant. Those who have used them declare them to have an invigorating effect; but the local action cannot be as powerful as when the electrodes are applied directly to the body.

Association Neurosis.

There is a neurosis to which I have elsewhere[1] called attention, and to which I ventured to give the name *association neurosis*. It includes a number of local affections, which are generally classified as hysterical, neurasthenic, traumatic, etc. It consists of a group of symptoms which, as a rule, have originated in some previous acute affection, such as inflammation, traumatism causing local injury or nervous shock, fever, or true neurasthenia, and which have become welded together by the process of association so that they persist as a distinct neurosis after the subsidence of the original disease. Many cases of hysterical joints are of this nature, as are also many of the so-called "railway spines" (spinal concussion) and neurasthenia (pseudo-neurasthenia).

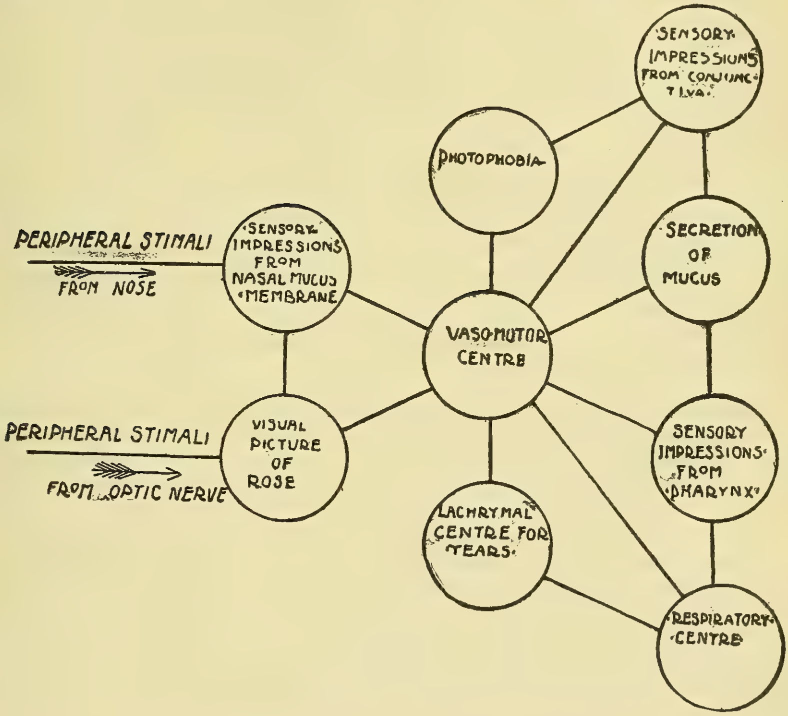
The constant and synchronous excitation of any group of symptoms tends to associate them together, so that in course of time the excitation of any one of them awakens the others, and they become perpetuated as a neurosis. The psychical element is a very large factor in keeping them alive. As long as the mind dwells upon them, consciously or subconsciously, it is very difficult for such a group of symptoms to subside, though the original physiological condition, such as an inflamed joint, muscular strain, or nervous shock, has ceased to exist. Auto-suggestion is, then, the active agent for maintaining the affection. For this reason, when such a neurosis has originated in the shock from a railway accident, recovery is apt to take place rapidly after the cessation of litigation, and in such cases an unjust suspicion is apt to be entertained of the assumed character of the disability. This pathology explains their persistence without accompanying physical signs of disease, and the recovery from them after a cessation of the mental agitation. They persist, however, in other cases, without evident mental cause, and when apparently the patient's mind is free from all anxiety regarding the condition. The neurosis is then maintained by the force of the association of morbid processes. Such a neurosis is sometimes termed "neuromimesis," and is not infrequently mistaken for more serious disease.

A case of coryza reported by Mackensie, of Baltimore, so aptly illustrates this neurosis that I am tempted to again cite it here, and, for convenience, quote from the communication above referred to. It shows the association of a *single mental state with a pure physical process*:—

> It was that of a lady who had been for years a terrible sufferer from rose cold, or hay fever. The disease became aggravated by the addition of asthmatic attacks, which complicated the coryza. She had become so sensitive that the number of exciting causes of

[1] Journal of Nervous and Mental Diseases, May, 1891.

an attack was very large. She was so sensitive to roses that the mere presence of a rose in the same room was sufficient to induce an attack. Suspecting the nature of her trouble, Mackensie obtained an artificial rose of such exquisite workmanship that it presented a perfect counterfeit of the original. One day, when the lady came to his office, after assuring himself by careful examination that she was perfectly free from coryza, Mackensie produced the artificial rose from behind a screen, where it had been concealed, and held it in front of her. Almost immediately a violent attack of coryza developed. Her eyes became suffused with tears, the conjunctivæ injected; the puncta lachryma began to itch violently; her face became flushed, the nasal passages obstructed, her voice hoarse and nasal; she complained of a desire to sneeze and tickling and intense itching in the back of the throat and in the auditory meatus; there was also photophobia and secretion of fluid from the nasal passages; to this was added a feeling of oppression in the chest and a slight embarrassment



of respiration. Examination showed the nostrils almost completely obstructed by swollen, reddened, and irritable turbinated structures, and filled with fluid. The mucous membrane of the throat was injected. At this point Dr. Mackensie stopped the experiment, thinking it had gone far enough, and the patient left the office with a severe attack of coryza.

The sequel is equally interesting. The true nature of the rose was shown to the patient, with the result that on her next visit she plunged her face into a bunch of real roses without ill effect.[1]

In this case we have all the phenomena of inflammation, a series of apparently organic processes set into activity by the force of an associated idea. It would seem as if the physiological processes of secretion of tears, secretion of mucus, vasomotor action (causing injection of tissue), pain, etc., were united into an automatic mechanism, and the whole

[1] Am. Journ. Med. Sciences, vol. xci, p. 45, 1886. The reader is referred to this interesting paper for accounts of numerous cases of neuroses, of various kinds, associated with a fixed idea.

connected (associated), as with a spring, with a higher visual centre, which, when touched, set off the whole mechanism. The principle here involved is an important one, and it will be well to bear it in mind when we come to consider other complex associations. It shows conclusively the possibility of an automatic nervous process of considerable complexity becoming established, and afterward excited anew as an independent neurosis by a purely physiological stimulus.

The whole process is illustrated by the diagram on preceding page.

Originally the peripheral stimuli which created the neurosis came from the nasal mucous membrane. Afterward, when the different centres had become welded together into an automatic whole, the entire process was exploded by the visual impressions from the optic nerve stimulating one of the associated centres.

It is not always that this neurosis is met with in a pure form. More frequently it is observed in a group of symptoms which have developed in the course of neurasthenia, or some other affection, of which it forms the most prominent feature: or the main disease having subsided somewhat, this group is left in still greater prominence. The association neurosis, in either case, stands out in relief as the chief disability, but a careful examination will show the existence of the original disease. Sometimes the neurosis remains hidden amongst a mass of neurasthenic or hysterical symptoms, from which it can be separated only by keen analysis of the existing symptoms and by investigation into their origin and occurrence.

The following cases will illustrate the character and treatment of this class of nervous affections:—

Observation 1.—G. B., young man about 25 years old. Referred to me by a specialist in genito-urinary disease for localized pain in the right inguinal region and frequent micturition. The patient was unable to retain his urine but for a short time, because of the pain which was produced by distension of the bladder. The pain, after continuing for a time, diffused itself somewhat over the lower abdomen. Obliged to get up frequently at night. As patient expressed it, probably somewhat hyperbolically, he "spent all his time in the water-closet." Secondary symptoms developed after the pain persisted for some time, such as faintness, pains in other parts of the body, etc. Muscular exertion seemed to bring on the pain, or he thought it did; so he had given up all exercise and was disinclined to work at his business as a salesman. Cross-examination brought out the fact that he attributed his trouble to his having strained himself during connection with a woman, for on the following day he noticed the pain, and at the same time had uncomfortable feeling in the urethra. These increased and frequent micturition followed. Was afraid at the time he had gonorrhœa, or had injured himself. These symptoms had persisted for a year, during which time he had been treated by several physicians, all of whom had told him "there was nothing the matter," but the neurosis had increased rather than decreased. In accordance with this opinion of physicians, his parents had shown little sympathy, and obliged him to work. In consequence of this home-treatment he had become morose, depressed, and ill-natured; considered himself badly treated. This had reacted on parents, etc. Confessed that the idea of having seriously injured himself had preyed upon his mind.

Treatment: Nature of malady carefully explained to patient, and strong static sparks applied to the seat of the pain. The strongest were borne without flinching, the patient appearing to enjoy the pain of the electricity.[1] He left the office free from pain for the first time for a year, and, of course, in high spirits. The pain returned after a number of hours, but with diminished intensity. Electricity was given in all seven times. After each sitting the intervals of relief became longer and pain returned in milder degree; ability to retain urine increased at same time. After seven applications, discharged well. In this case the

[1] This is not uncommon, when the original suffering has been persistent and severe.

symptoms (pain, hyperæsthesia of bladder, etc.) had probably originated in some muscular strain and urethral irritations. After the cessation of the morbid physiological process, the symptoms had by association become bound together with other bodily sensations and movements, such as distension of bladder and movement of the abdominal muscles, and had persisted as a habit neurosis. The physiological excitation had prevented them from subsiding. The electricity not only allayed his mental fears, but broke up the association by suppressing the pain. There were no hysterical symptoms.

Numerous personal observations might be cited to illustrate this neurosis. A few only will be mentioned here, as it is not desirable to introduce the accounts of more cases than are necessrry to make clear the view maintained here of the pathology of the affection.

The following, already published, is a case in point:—

Observation 2.—A woman, 41 years of age, came to me complaining of paroxysms of pain, from which she had suffered for ten years past. The pain was located in the epigastrium, and sometimes was accompanied by pain under the right eye and in the soles of the feet. It was described as hot and burning in character, "just as if you put your finger on the stove" (as she said). These paroxysms came on nearly every day, and lasted from one minute to half an hour; when occurring at night, she was unable to obtain any sleep. As a rule, during the day she "could not go over two hours without pain" of greater or less severity. Physical examination showed nothing abnormal beyond a tender spot at the junction of the sixth or seventh rib with the sternum, on the left side. She was of a nervous, anxious temperament, easily worried, and disturbed by trifles. Cross-examination revealed the fact that ten years ago she received a great nervous shock in the form of some "terrible news." She thinks the first pain came simultaneously with the nervous shock, and she ascribes her condition to that accident. At that time she became "numb all over"; "for four or five months could not sleep at all"; felt dazed and confused in mind; if spoken to, voices sounded "away, away off." This is the best description I can obtain of her condition at that time. At present any mental worry or excitement causes a paroxysm; for example, after waiting two hours in my office without seeing me, she went away, under the disappointment, "all doubled up with pain." Physically she is in good condition; is strong and can walk long distances; her spirits are easily depressed or elevated; overtire, worry, or disappointment —in fact, anything that upsets her mental equilibrium—brings on a paroxysm.

The treatment in this case was static electricity. After a few sittings the paroxysms of pain ceased; she was in every way better mentally and physically. She said she "felt like a different woman." She was free from any attack while under observation, for a period of four or five weeks, when she was discharged.

The order of events in this case I conceive to be as follows: Ten years ago this patient was attacked with an acute nervous illness, of which two prominent symptoms were mental distress and epigastric pain. These two processes were so frequently associated together that a reflex physiological connection became established between their nervous centres; the presence of the one then necessitated the reproduction of the other; and when, later, recovery from the acute illness occurred, the association being persistent, the presence of any physiological excitement or anxiety was necessarily accompanied by a paroxysm of pain. The pathological condition lay in the association of two centres, and not in the centres themselves. The treatment resulted in the breaking up of this association, probably by means of suggestion.

One curious mode by which this neurosis may arise is pure mimicry, —that is, where simple observation of the person affected with a disease is sufficient to induce similar symptoms in an impressionable subject. This is a form of auto-suggestion. Secondary symptoms may be added to the suggested or mimetic ones, oftentimes as the result of emotional disturbance, and the whole may become grouped together by association

into a true neurosis, which may persist by itself indefinitely. The following is a case in point:—

Observation 3.—A certain person was affected with cerebral syphilis, from which disease he eventually died. His eyes were also attacked by the disease, and he presented an unpleasant sight. A friend of this person, who saw him frequently, was much impressed by what appeared to him a horrible disease. Syphilophobia developed, and he began to imagine that he had the disease himself. Soon his eyes began to pain severely, and he ran from one physician to another, without relief, until one told him that the pain in his eyes was purely mental, and then this symptom subsided. Meanwhile, a train of symptoms had developed, which he described in this way: First, the idea of the man with the real disease kept coming into his mind. Then he thought that he himself might have it. Then he became frightened; his body was bathed in sweat, and he felt nauseated. Then severe pain in the top of his head was added; he felt weak, depressed in spirits, and had insomnia. He had twichings in the muscles of his arms and legs. His nights were disturbed by horrible dreams. At first these symptoms only developed when the idea of the syphilitic patient was present to his mind. Later they became more persistent, lasted a longer time, until, finally, anything that depressed his mental equilibrium or overtired him brought them on. When he presented himself for examination, about six months after the beginning of the neurosis, he was attacked by this group of symptoms several times a day, the exciting influence being usually some unpleasant idea or overtire. He recognized perfectly the nature of his malady, but said it was absolutely impossible for him to control it. He was fully aware of the effect of his imagination in producing these symptoms. Pain in the head, mental depression, and insomnia were the most distressing of the symptoms, and beyond his control. On a previous occasion he had suffered from a very similar train of symptoms, due to the fact that he was bitten by a cat, and imagined he had hydrophobia. Nausea and vomiting had occurred at the beginning of both these attacks. This patient has been cured by electrical treatment and physical hygiene.

Electricity is a very powerful agent in curing this neurosis. It probably acts in two ways: first, by inhibiting by local stimulation one or more of the symptoms composing the group, and thus breaking up the association; and, second, by suggestion allaying the psychical factor and allowing the process to subside. I have found static electricity very valuable for this purpose, both in the form of breeze and sparks. It should be given locally for the individual symptoms, and generally for its refreshing, tonic effect. Faradism and galvanism also work well, but I have relied more on the static variety, without, however, having made comparative tests. The technique is the same as in other neuroses.

The aim of treatment should be to inhiblt, if possible, the various individual symptoms, so as to break up the morbid association. For this purpose electricity should be applied so as to attack separately the various psychical and bodily symptoms. The same methods are applicable as in the treatment of the psychoses and neurasthenia, which have already been described. The next important problem should be to do away with such psychical influences as tend to keep up the neurosis. Auto-suggestion plays a very conspicuous part in this respect, and, so long as the patient's mind constantly dwells upon his ailment, it is difficult to accomplish much in the way of relief. Therefore it is well, with most patients, to begin by explaining carefully the nature of the malady and giving assurance of the absence of serious disease. When

neurasthenia or hysteria co-exists, as it frequently does, it should be independently treated.

Electricity does not always effect a cure in these cases. Sometimes, as in other affections, its results are very disappointing; and, although, in some cases, we may feel absolutely sure of the correctness of our diagnosis, it seems almost impossible to break up the pathological association. An instance in point is the case of neurasthenia already referred to on page K–54 ("Observation 3"), where, although I was firmly convinced that the great mass of symptoms were dependent upon a morbid association process in a neurasthenic subject, yet I found it impossible, by electricity or any other treatment, to effect a cure. The patient suffered from every kind of neurasthenic symptom. There were gastric, intestinal, cardiac, cephalic, and vasomotor disturbances, combined with malnutrition, all associated together; and the presence of one, as a little dyspepsia, brought with it the whole train of other disturbances, like the explosion of a train of gunpowder fired by a match. The patient was treated by the Weir-Mitchell rest-cure, but, although fattened and improved, immediately broke down again on resuming her social duties. The nature of the malady was carefully explained to her, but, although her co-operation and faith were given most generously, little permanent result was effected. Electricity was without benefit. The final history of this patient is instructive. After she left my hands she tried "Christian Science," and was cured in two weeks. Her faith literally "made her whole." Therefore, it may be said that, while some cases yield like magic to treatment, others are very rebellious, although every case is susceptible of cure.

Traumatic Neuroses.

As traumatic neuroses include a number of different affections, such as traumatic neurasthenia, traumatic hysteria, nervous shock, etc., the treatment of them is more properly included under the head of these same affections when due to other causes than traumatism. The treatment of traumatic neurasthenia, for example, differs very little from the treatment of the same neurosis when occurring under other conditions, and what has been said of the effect of the electrical treatment of these idiopathic affections is true of them when due to injury. There is much difference of opinion among neurologists regarding the prognosis in such cases. In the opinion of the writer, however, both traumatic hysteria and traumatic neurasthenia tend toward recovery,—much more so than do the same affections when occurring idiopathically. There are, however, marked exceptions to this general rule. As has been before so often insisted upon, the presence of litigation and other conditions tending to keep alive the symptoms is always an obstacle in the way of electrical as well as of all other treatment, and little can be expected in the way of cure so long as such conditions exist. For the electrical treatment

of these various neuroses the reader is referred to what has already been said.

There is a form of traumatic neurosis, however, which, perhaps, requires separate discussion. Although most cases of injury to the nervous system may be classified under one of several well-recognized types of disease, organic or functional, we sometimes meet with other cases which present groups of symptoms, of irregular distribution and complex in their arrangement, which cannot very well be classed under any recognized affection of the nervous system. They seem to be *sui generis*, and a distinct pathology has been claimed for them by the German school of neurologists. To them the term "traumatic neurosis" has been more distinctively given. It has been claimed that they are due to anatomical changes in the central nervous system, such as capillary hæmorrhages and inflammatory softenings, which have been induced by the physical shock or concussion. The fact that some of these cases do not recover—and a few have ended fatally—has been adduced in support of some such serious pathological condition. The old dogma of cerebro-spinal concussion has thus taken on a new form. In the opinion of the writer, however, the symptoms in most, if not all, of these cases are to be looked upon as an expression of profound physiological, and not of anatomical, shock. It is the overstimulation of the central nervous system by psychical and sensory impressions that has induced the complex group of symptoms, and not the physical injury *per se.* It seems to the writer that, notwithstanding the vigorous opposition of a certain school, particularly in Germany, the tendency of modern neurologists is toward this physiological view, rather than toward that of anatomical degeneration due to physical concussion.

Psychical and sensory impressions, when sufficiently intense, tend to be propagated beyond their normal limits, and to "slop over," so to speak, along adjoining nerve-tracts until they reach remotely-connected centres, and thus to induce symptoms which would not be awakened by normal and moderate stimulation of the same kind, in much the same way as when a river, owing to a freshet, overflows its banks and inundates the adjoining country, or when an electric storm induces in telephone- and telegraph- wires currents which ordinarily are inappreciable, and plays havoc with the recording instruments. Symptoms which have once been excited in this way do not easily subside, but persist as a neurosis. In a minor degree this has been observed by every one in the tremor of the limbs, in præcordial anxiety, headache, and what not, brought on by slight mental shock, emotion, or fear. Imagine all these to be intensified a hundred times, and see how easily a symptom-picture may be produced similar to that exhibited by these traumatic neuroses. Such a symptom-picture would be neither one of hysteria nor of neurasthenia. More properly it may be designated as a traumatic neurosis, as it is only by traumatism that such a state of things can be excited.

Whether, more than this, deeper anatomical degenerations occur in exceptional cases as the result of nervous shock or concussion, and which are the direct cause of the clinical phenomena, or whether, when found, they are not simply the concomitants of the nervous shock, are questions on which we are not at present in a position to dogmatize, although there is little proof either way. It is possible that, when these finer anatomical degenerations are found, they are only the secondary result of long-standing functional disease.

Limiting, then, for the purpose of this article, the term " traumatic neurosis " to cases of this kind, it may be said that electrical treatment is often capable of producing a very beneficial influence upon them. Provided that due care is taken to remove all unfavorable surrounding conditions, and to subject the patient to favorable hygienic conditions, electrization can be often used with great advantage. Symptoms which are distressing can frequently be overcome, and the patient rendered comfortable. Cases of minor severity are often rapidly cured. It is almost always desirable to give electricity a trial, as an adjuvant, at least, to other methods. The indications for its use and the technique are the same as for the treatment of neurasthenia and allied affections. Psychical symptoms can often be allayed by either galvanism to the head or by the static breeze. Insomnia and cephalalgia may sometimes be decidedly benefited. They should be treated as has already been described elsewhere.

Pain in the form of false neuralgias, which are so common in affections of this kind, can almost always be relieved by electricity. These neuralgias, though frequently of a psychical nature, are often very intense, so much so as sometimes, when long continued, to produce by themselves an hysterical condition. It is here that electricity becomes a most useful agent, and serves to keep the patient comfortable without the use of drugs and other undesirable remedies. Often local pains due to real injuries to parts, such as neuritis, are relieved, and the patient kept fairly comfortable, while time—if it be only that—effects a cure. General faradization or galvanization sometimes works well in toning up the general condition, but it is the local symptoms which we can particularly hope to affect.

Paralyses and anæsthesiæ behave as when occurring in the course of hysterical and allied neuroses. Some cases are uninfluenced by any treatment, and we can do little more than make the patient more comfortable, and trust to time, change of scene and surroundings, and other hygienic measures to eventually bring about a restoration to health. It is not always sufficiently understood that, while litigation is in progress, as is apt to be the case in almost all of these cases, no treatment of any kind will be of service. The most vigorous therapeutic measure is to hasten the settlement of the case, and put the patient in a position to undertake a rational treatment. It certainly is rarely of use to employ

electrization until this be done,—at least, with a hope of cure; although, the symptoms may be allayed and the patient made more comfortable. The technique, then, of these neuroses is similar to that already described when speaking of neurasthenia and hysteria, and the reader is referred to what has been said there.

DISEASES OF THE SPINAL CORD.

By WILLIAM JAMES MORTON, M.D.,

NEW YORK.

Introductory.

The impartial practitioner will to-day as well hesitate to affirm that electricity has no value in the treatment of diseases of the spinal cord as to claim for it an excessive value. Its utility in this especial class of diseases is to be measured both from the stand-point of our present knowledge of the efficacy of electrotherapy and from that of the peculiarly-incurable nature of most spinal-cord diseases.

While, from either point of view, the present outlook does not, in a large class of cases, justify sanguine predictions of positive cure, neither does it, on the other hand, sanction failure to treat these diseases by electricity; for in some instances the diseases in question are cured by this means, in many more they are arrested, and in but a very small number does a judicious use of electricity fail to palliate the severity of the symptoms. We cannot sweep away simply by expressions of skepticism the array of brilliant results reported by men like Erb, Benedikt, Meyer, Remak, Ziemssen, Eulenburg, Brenner, Lewandowsky, and the great German school; like Duchenne, and a host of his countrymen, of the brilliant French school; like Russell Reynolds, Hughes Bennett, Althaus, de Watteville, and a multitude of others, of the English school, whose recent work is of inestimable value to the cause of scientific electrotherapy.

In our own country the pioneer efforts and faithful labor of Beard and Rockwell—far in advance for the time at which they were written—are still valuable for reference, and claim an historical interest dating back to 1863. Among modern writers, most valuable information may be gained from works by Massey, Goelet, Bigelow, Liebig and Rohé, Wellington Adams, Roberts Bartholow, and others.

We cannot, in short, cast to one side, much as we respect the views of Möbius and his followers, the present state of the art of electrotherapy, built upon clinical experience, though we must admit that it is almost pure empiricism. But, while according full merit to empirical results, we must also frankly admit that electrotherapy is still in its infancy. We have seen, only in recent years, electricity in the industrial arts just emerging from a similar stage of progress, and we see to-day, as a result, inventions and discoveries which, without exaggeration, are termed marvelous. Electricity has revolutionized chemistry; has revolutionized physics; has revolutionized the industrial arts and trades of

the world; and it would, indeed, be an anomaly if its influence were not to extend, with new meaning, to medicine.

When the present nascent electrical science shall at last make its influence felt in medicine, we shall have a new art of electrotherapy as incomparably superior to the present as is the modern dynamo and electric-lighting installment of a great city to the few cells and bits of carbon of Sir Humphry Davy's first laboratory arc-lamps. Already the medical profession is feeling this influence. Not only is the electrical engineer beginning to carry his studies into the fields of biology, but the physician who intends to use electricity is beginning to acquire a knowledge of electrophysics after the manner of the engineer. There can be but one lasting basis of electrotherapy, and that must be built upon the physics of electricity.

That electrotherapy is obliged to admit enormous shortcomings in the past and up to the present is due to many causes. Not the least of these has been its universal employment by those who have no knowledge of its properties, physical or physiological. Such administrators were as unfamiliar with the fundamental conceptions of current-strength, resistance, difference of potential, or density, as they were of electrolytic action, cataphoresis, vasomotor effects, and the laws of nerve and muscle irritability. It was presumed that ignorance could direct the management of an agency which, more than any other, requires knowledge. But, granting the most thorough possible knowledge of the properties of the electric current, the difficulties of the electrotherapist are but little diminished. He is still confronted by the obstacles presented on the physiological and the pathological side; the real nature of the processes of health or of disease are but little known; the diseases themselves, particularly of the nervous system, when once established are peculiarly intractable. Electrophysiology itself is in a state of confusion, and requires that most of its work should be revised and its contradictions eliminated.

Indeed, no one knows what electricity is, and we may be said to be treating the unknown with the unknown, and with a technique as whimsical as irrational, and as necessarily empirical as such a situation would necessitate. There is but one onward path open in a situation such as this, and that is a most thorough study of the properties of electricity; of its effects upon living tissue; a quick utilization of the best physiological and pathological information; and a careful building up of the data derived from rigidly-conducted clinical experience. And, bad as the situation is, electro-therapeutics would seem to the writer to be of more actual value and fuller of promise for the future, for the cure of established disease, than other therapeutic measures of a medicinal nature. The triumphs of medicine thus far have been in alleviating pain and in the prevention of disease rather than in the cure of actual and active morbid processes. And so far as relates to the diseases of the spinal

cord,—diseases in most instances well advanced before they are recognized,—it is believed, by many who have excellent opportunities for observing, that electricity is of more value than any medicinal treatment, and, on the whole, of more value than any other treatment. If any reservation were to be made in this expression of opinion, it would be in favor of hydrotherapy.

It will be seen, from the tenor of the foregoing remarks, that there is no classical electrical treatment of diseases of the cord; no fixed and positive method which can, in all cases, be said to be superior to another. The methods pursued by various authorities vary according to their pathological views, according to physiological views, and according to the special properties thought to exist in special forms of current, whether galvanic, faradic, or franklinic, or, finally, according to simple empiricism.

In the special class of diseases now under consideration the prospect of cure will be greatly improved when perfected clinical observation shall enable us to make an earlier positive diagnosis than now seems to be practicable; for, as a rule, these cases come under treatment at a period when the nerve-cells and fibres have suffered destruction and cannot be restored either by electricity or by any other known measure. In fact, it seems as if the diagnosis were often only finally made by reason of the symptoms amply afforded by nerve-elements whose function was extinct. Could the early stage of the process be detected, there would be good grounds for expecting to arrest it. This is demonstrated by the history of cases, ordinarily progressive, where electrical treatment arrests the disease; the presumption in such a case is that, at a certain stage of progress, the morbid process may cease or even become entirely replaced by a normal process.

Recognizing these difficulties, we shall be better able to measure our successes judicially and less likely to entertain extravagant hopes which, as a rule, have led to disappointment or to a final and unreasoning skepticism as to the value of electricity in the treatment of disease.

Before taking up the special applications of electricity in diseases of the spinal cord it is essential to determine, with all possible exactness, the data of the problem to be solved. These data cannot here be treated of exhaustively; in a general sense, they include the entire art and science of medicine, for, the more highly educated and skilled the physician may be, the more intelligently will his therapeutic measures, particularly the electrical, be applied; in a special sense these data will be found by reference to other pages of this work. It has seemed, on the whole, best and easiest to the writer to present the small but important section of this work possible for him to find time to contribute by cursorily traversing the field of some of the general principles involved, with a view of avoiding and discouraging mere rule-of-thumb practice; for such practice will always prove to be unsatisfactory. It belongs to

the hospital or trained nurse, and not to the physician. The data referred to may be conveniently classified into such as relate to:—

I. The nature of the disease.

II. The mode of manifestation of electric energy employed, viz., the kind of current.

III. The action of the electric energy upon living tissue and the properties of the current.

IV. Methods of application and treatment of special diseases.

I. The Nature of the Disease.

There are many diseases and morbid conditions of the spinal cord which do not, at present, fall into the category of those which long usage and experience have established as appropriate to the use of electricity. Examples of these are especially the acute diseases.

But it is noticeable, in this respect, that usage and empiricism are progressively modified in direct ratio to the more accurate knowledge gained of the physiological functions of the cord, the nature of the pathological processes which take place in its organic structure, and of the nature of the effects which electricity may produce.

It is obvious that if the practitioner is guided alone by an accurate knowledge of the disease on the one hand, and by an equally accurate knowledge of the effects of electricity on the other,—as, for instance, its excitatory action upon the protoplasmic elements of the nervous tissue, its electrolytic or chemical effects, its vasomotor and circulatory effects, its cataphoric and other familiar effects,—he will find himself possessed of a much greater latitude of action than if guided by any rules founded merely upon experience. Electricity is too often regarded as merely electricity, without any discriminating attention directed to the very marked distinctions between the effects it is capable of exerting. From this gross point of view it may as often do harm as do good. A single instance of many will illustrate the importance of attention to particular effect desired to be attained in contradistinction to a hap-hazard method. No fact, perhaps, is better established than that there is a transference of fluids during the flow of the continuous current from the positive to the negative poles, viz., cataphoresis. To a tissue already, from any cause, too rich in fluids it might be undesirable to apply a negative pole and increase the fluidity. On the contrary, a positive pole would cause fluid depletion,—an effect more than merely mechanical when we recall the fact that the tissues themselves are semi-fluid, susceptible to cataphoric action, and that that action must therefore not alone affect interstitial fluids, but also the protoplasmic substance of the cells themselves. If to the fluid depletion we add the accompanying diminution of the salts produced by electrolytic action, we may conceive of a tissue as doubly robbed of the salts essential to its vitality, and thus checked in its morbid progress.

A pathological basis of fact, or at least a pathological hypothesis, is essential to the treatment of disease by any therapeutic measure. And if this sort of basis is essential as regards the disease, it is equally essential as regards the remedy. It is especially essential as regards the use of electricity, since this agency represents not a single action, as is the case of most drugs, but a multiplicity of actions, some of which are recognized with scientific exactness, while others are yet unknown. This, again, is one of the reasons why, as has already been remarked, there are no classical and invariable rules of procedure for treating diseases of the spinal cord, and why a general survey of the field is an essential preliminary to special electro-therapeutics. Essential to such a general survey as to the nature of the disease is a brief enumeration of the diseases to which the cord is subject; an equally brief glance at certain special anatomical features relating to localization; and, finally, some reference to our present knowledge of those finer pathological processes which it is hoped to antagonize or arrest by the use of electricity.

Classification and Enumeration of Diseases of the Cord.—Our present knowledge of the pathological processes which constitute the different diseases of the spinal cord does not justify an attempt to classify them according to the nature of the disease alone. A simple enumeration will answer all practical purposes. This we may conveniently adopt from the classical work of Gowers; and without elimination, in order that the entire field for effort may lie before us. It is needless to add that for the treatment of some of these diseases the use of electricity would be wholly unjustifiable; in others permissible, but lacking the sanction of experience; while in others, again, like locomotor ataxy, chronic myelitis, primary lateral sclerosis, anterior poliomyelitis, progressive muscular atrophy, and functional and nutritional diseases of the cord, electricity has long since established its efficacy as both palliative and curative. We think it at least conservative to state, in this connection, that no practitioner, having the welfare of his patient at heart and keeping in mind the traditional office of the physician,—which is to heal,—can, even in the present state of the art and science of electro-therapy, refuse to the patient the aid which electricity may afford.

The diseases to which the spinal cord is subject are :—

Special Diseases of the Cord.
- Injuries of the spine.
- Caries of the spine.
- Vertebral exostoses.
- Syphilitic disease.
- Erosion by aneurism.
- Hydatid disease.
- Diseases of the articulations.

Diseases of the Membranes of the Cord.
- Spinal meningitis (pachymeningitis leptomeningitis, acute and chronic).

Diseases of the Cord.
- Anæmia and hyperæmia.
- Inflammation—myelitis.
- Abscess.
- Embolism.
- Chronic myelitis.
- Compression myelitis.
- Anterior poliomyelitis : atrophic spinal paralysis.
- Acute ascending paralysis.
- Divers' paralysis.
- Hæmatomyelia.

Degenerations of the Cord.
- Locomotor ataxy.
- Primary spastic paraplegia.
- Ataxic paraplegia.
- Pellagra.
- Hereditary ataxy.
- Simple senile paraplegia.
- Progressive muscular atrophy.
- Arthritic muscular atrophy.
- Idiopathic muscular atrophy.
- Thomsen's disease.

Tumors of the Cord.

Cavities and Fissures in the Cord: Syringomyelia, Hydromyelia, Hydrorrhacis Interna.

Morvan's Disease.

Spina Bifida.

Traumatic Lesions of the Cord.

Functional and Nutritional Diseases of the Cord.

Anatomical and Physiological Observations.—For the special anatomy and physiology of the spinal cord the reader is referred to the usual authorities and to whatever may seem essential to this part of the subject when individual diseases are referred to later on. Some particular features of its anatomical situation in relation to the electrical conductivity of structures and fluids which surround it will be better considered by themselves, and in connection with the important question of whether the spinal cord can, by ordinary percutaneous treatments, be reached by the electric current or not.

There is one line of inquiry essential to the electrical more than to any other treatment. This relates to the localization of the part of the cord affected by disease, and a consequent direct localization of the current to that part, or of an indirect localization of the effect of the current to the same part by adapting its administration to a proper portion of its peripheral representation. As a whole, the spinal cord serves as a pathway for the conduction of motor impulses from the brain and for sensory impulses to it; it contains centres for reflex action; it also contains centres which, in connection with the sympathetic system, govern the action of the blood-vessels and the viscera, and, finally, the state of its nutrition affects the nutrition of every part to which its nerve-fibres are distributed.

Its relations to the entire motor sphere may be most easily grasped by keeping in mind Gowers's division of the motor path from the cortex of the brain to the muscles into two segments, an upper and a lower, each consisting of a ganglion cell above, a nerve-fibre next, and finally the peripheral ramifications of the latter. The upper or "cerebro-spinal" segment would thus consist of a cortical ganglion cell, of its pyramidal fibre, which traverses both brain and cord, and of the termination of the latter in the gray substance of the anterior cornu, while the lower or "spino-muscular" segment would begin in the motor cells of the anterior cornu, and proceed by its anterior root and nerve-trunk to its termination in the muscle. The two segments are brought into conductive relation by contiguity, if not by continuity, by means of the fibrillary nerve-plexus of the anterior cornu. "We shall see, for instance," says Gowers, in referring to this division of the motor pathway, "that diseases involving any part of a segment produce similar

effects, however diverse their nature, while there is a fundamental difference between the effects of disease of the two segments."

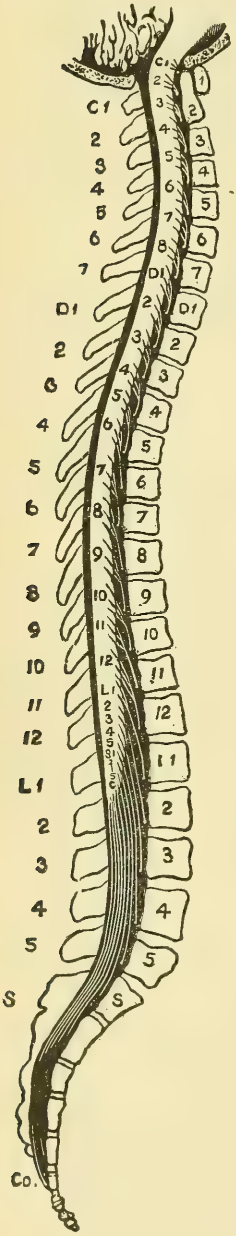
While it is known that motor, sensory, and reflex functions are represented by corresponding spinal mechanisms of more or less definite area, especially in a vertical direction, still, a very exact localization of these centres is not as yet possible. It is certain that groups of muscles are represented in certain segments of the cord; there is also a progressive representation of cutaneous sensation in the posterior nerve-cells, while the reflex centres have a fixed relation to the intermediate gray substance lying between the in-going and the out-going nerves which go to constitute the reflex arc of each spinal segment.

The bearing of these facts upon the electrical treatment of diseases of the cord is most obvious not only in diagnosis, but in treatment. From both points of view localization is important. In a case of progressive muscular atrophy treated by the writer, in which the disease had caused atrophy of the small muscles of the hand, and was already causing fibrillary twitchings, exaggerated muscular excitability, and alterations of electrical excitability in the muscles of the forearm, complete arrest of two years' duration followed localized polar treatment over the sixth, seventh, and eighth cervical and first dorsal nerve-origins.

This case is cited merely in its relations to localization. There can be no hesitancy in adopting the rule to treat diseases of the cord *in loco morbi*, and to this end the seat of the disease must be carefully located.

The spinal-cord " segment " is a convenient unit division for localization of diseases of the cord. It is that portion of the cord from which each pair of spinal nerves arises. Each pair at its level of origin, viz., at its segment, is situated on a plane considerably above its level of exit through the corresponding vertebral foramina. The lower down the cord the origin of the pair of nerves, the longer distance must the pair extend to reach its foramina, and finally a point is reached at the second lumbar pair, where all the pairs which arise below it find their foramina of exit at a level of the vertebral column, below the lower end of the cord. The vertebral spinous processes, which are easily felt beneath the skin, are our only guide from the outside to the position of these segments. Did each spinous process correspond, with any reasonable degree of accuracy, with each segment, the localization of the latter would be easy. But it does not. The spines at their tips, where they may be felt, are not on a level with their bodies, and consequently not on a level with the foramina, and much less, as we have seen above, not on a level with the origin of the nerve-pairs. It is, therefore, essential to keep in mind the relation of the spinous processes to their vertebral bodies and of the exit-foramina in these bodies to the origin of the nerve-pairs. The following diagram, showing the relations of the spinous processes to their bodies and to the origin of the nerve-roots,

viz., to their spinal segments, taken from Gowers, will make these relations clear at a glance; and the table on opposite page, compiled by Gowers and taken from his book upon the nervous system, will prove of inestimable value to the practical application of electricity to the proper peripheral areas.



By reference to the diagram it will be seen that, as pointed out by Gowers, the *vertebra prominens* is opposite to the first dorsal nerve-root, and that from the third to the tenth dorsal the spines correspond to the second root below; the eleventh spine corresponds to the first and second lumbar nerves; the twelfth to the third, fourth, and fifth; the first lumbar to the first, second, and third sacral nerves, while the tip of the cord is opposite the upper part of the second lumbar.

A convenient method of locating the lower end of the cord when the spinous processes, for any reason, are difficult to feel, is to follow the last rib with the fingers to its junction with its vertebra, which is the last dorsal. And, in a general way, the lumbar enlargement of the cord is located between the first lumbar and seventh cervical, while the cervical enlargement is located above the seventh cervical.

The preceding considerations relating to the positive localization of the electric current to the seat of disease are advanced, in the main, in reference to the direct electrization of the cord. But the cord may be affected indirectly, by aid of the extension of its continuity, into a peripheral distribution. Each segment, comprising within itself, or in connection with adjoining segments, a centre for the spinal representation of the motor, sensory, and reflex anatomical mechanism and functions, has a corresponding representation in the periphery, in the form of the ramifications of the spinal nerves. This peripheral distribution of the nerves may also be directly influenced by electric currents. Indeed, to this method of treatment, or to this effect, when, in the course of spinal-cord disease, peripheral nerves and their muscles are treated, is to be attributed most important results.

TABLE SHOWING THE APPROXIMATE RELATION TO THE SPINAL NERVES OF THE VARIOUS MOTOR, SENSORY, AND REFLEX FUNCTIONS OF THE SPINAL CORD.

MOTOR.	(NERVES.)	MOTOR.		SENSORY.		REFLEX.
	C. 1	Small rotators of head.	1		1	
St.-mastoid. Upper neck-muscles. Upper part of trapezius.	2	Depressors of hyoid.	2	Scalp.	2	
	3	Lev. ang. scapulæ.	3	Neck and upper part of chest.	3	
	4	Diaphragm.	4	Shoulder.	4	
	5	Serratus. Flexors of elbow. Supinators. (Shoulder-muscles.)	5	Arm, outer side.	5	Scapular.
Lower neck-muscles. Middle part of trapezius.	6	Ext. wrist and fingers.	6	Radial side, forearm and hand; thumb.	6	
	7	Ext. elbow. Flex. wrist and fingers. Pronators.	7	Arm, inner side; ulnar side of fore-arm and hand; tips of fingers.	7	
	8	Muscles of hand.	8		8	
	D. 1		1		1	
Lower part of trapezius and dorsal muscles.	2	Intercostals.	2	Front of thorax.	2	
	3		3		3	
	4		4		4	Epigastric.
	5		5		5	
	6		6	Ensiform area.	6	
	7	Abdominal muscles.	7		7	
	8		8	Abdomen (umbilicus, 10th).	8	Abdominal.
	9		9		9	
	10		10		10	
	11		11		11	
	12		12	Buttock, upper part.	12	
	L. 1		1	Groin and scrotum (front).	1	Cremasteric.
Lumbar muscles.	2	Cremaster. Flexors of hip.	2	Thigh: Outer side. Front. Inner side.	2	Knee-jerk.
	3	Extensors of knee. Adductors of hip.	3		3	
Peroneus, l. Flex. of ankle. Ext. of ankle.	4	Extensors and adductors of hip.	4		4	Gluteal.
	5	Flexors of knee.	5	Leg, inner side.	5	Foot-clonus.
	S. 1	Intrinsic muscles of foot.	1	Buttock, lower part. Back of thigh. Leg and foot. Except inner part.	1	Plantar.
	2		2		2	
	3	Perineal and anal muscles.	3	Perineum and anus.	3	
	4		4		4	
	5		5	Skin from coccyx to anus.	5	
	Co.		Co.		Co.	

One characteristic and almost invariable effect, due to electric stimulation of the peripheral nerves and their end-organs, is the improved nutrition of the patient. It is a matter of common observation, in a clinic where the poor are treated by electricity alone, and in a great variety of methods, local and general, that they make a rapid increase in weight and in general health, irrespective of the progress which may ensue in the disease for which they are under treatment.

From many points of view, there should not be drawn as hard and fast a line between direct central treatment and treatment of the periphery as would, at first thought, seem justifiable from a gross division of the nervous substance itself into cord and peripheral nerves. For there is, in fact, no structural dividing-line between the two. The axis-cylinder of a motor peripheral nerve is the actual prolongation of the process of a spinal ganglionic nerve-cell; its nutrition is dependent upon that of the cell; it can generate nerve-energy like the cell, for it can be stimulated independently of it; and its structural continuity may be traced into the muscular protoplasm, with which it shares at least molecular continuity. The sensory peripheral nerves, while they conduct upward, degenerate downward, and their vitality depends upon the vitality of the cells of the ganglia of the posterior nerve-roots. Their peripheral endings may be conceived of as generators of nerve-energy when acted upon by external stimuli, and their continuity with the spinal-cord cells is as definite as is that of the motor nerves. Granting ourselves this conception of the integrality of the peripheral nerves and the cord, in relation to the electrical treatment of either of them, we shall be better prepared to recognize the very great value often to be derived from treatment directed to the periphery, as well as to the centres.

The value of a localization of motor, sensory, and reflex centres, to at least fairly accurate levels of the cord, is obvious to the neurologist in diagnosis of the extent of transverse lesions. The same localization, viewed reversely,—viz., to affect the cord at certain levels by the electric stimulus directed to given peripheral areas,—is of equal value to the electro-therapeutist. How great the effect of in-going impressions upon central ganglionic cells may be is evidenced by some recent experiments of Hodge, in which the nerve-cells in the posterior ganglion of cats were caused, by continued electric excitation of their peripheral nerves, to shrivel to less than half their size, and to even suffer conspicuous alterations in the appearance of their nuclei,—effects which it required the animal a long time to recover from, under the best influences of rest and nourishment.

Just how much peripheral stimulus will do harm and how much will do good, in a given morbid condition of the cord, is yet to be determined by physiological experiment and clinical observation. But certain it is that decided effects may be produced in this manner. In this relation we may mention the treatment of locomotor ataxy by peripheral excitation with the dry faradic brush advocated by Rumpf, and the method long pursued by the writer of treating appropriate peripheral areas, both in spinal cord and in disturbances of general nutrition, by the fine friction sparks and the long, powerful sparks of franklinic electricity. The method of general faradization advocated by Beard and Rockwell would fall, in its general effects, under the same category, as well, also, as similar effects upon the general well-being of the patient derivable

from electric baths, though to the latter two should also be added the effects of nutritional activity due to the contractions produced in muscle-tissue.

Of the sensory impressions—cutaneous, and from the muscles in posture, etc.—that travel in afferent pathways a large majority fail to reach our consciousness; their energy is expended upon intermediate ganglionic centres, into which they sink, so to speak, with a corresponding transformation of energy, into some other form, mainly as motor-reflex energy. The spinal gray substance receives an unusually large quota of this stream of influence from without,—and the recognition of this fact cannot fail to be suggestive of the employment of the same pathways for the intentional propagation of artificial stimuli to the same centres, with a view of creating effects upon their nutrition.

Pathological Processes in the Spinal Cord.—It is peculiarly unfortunate, in dealing with the curative aspect of an agency as definite and as mathematical, so to speak, in many of its phenomena as electricity is, that so little is known of the real nature of the initial pathological changes which take place in most of the diseases of the spinal cord. As has already been remarked, electricity is only too often called upon to restore the structure of nerve-cells and fibres already, both structurally and functionally, past recovery,—to reconstruct, as it were, an organized animal structure from its ashes.

Fortunately, nerve-trunks and spinal-cord strands do not, as a rule, suffer at the same moment equal impairment of all their fibres,—while some are degenerated, others are either intact or at various stages. The same is true of the ganglionic cells. Hence, if the disease is arrested, as it often is, it follows that there exists a stage of development at which electricity is, in a real sense, curative. If ever we are able to detect this stage in the first cells and fibres attached, we shall be as well able to arrest it one time as another, and thus be enabled to improve our present prognosis. As will be seen, under "The Action of Currents upon Living Tissue," the physician has it within his selection to project against the diseased process certain specific actions of the current. He may excite the irritability of the diseased part; he may overexcite, and thus benumb it; he may, by electrolytic action, deprive a tissue of the salts so essential to its nutrition; he may accumulate fluids at a given point and remove them from another by cataphoresis; he may produce capillary stasis and vasomotor dilatation; he may produce simple mechanical disturbance of tissue; he may set up revulsive effects. These and other effects, either combined or singly, he has at his disposal. And yet, if he is ignorant of the pathological process to be combated, his electrical armamentarium will avail him but little, and he is still driven back to the empirical basis. This basis it must be our continual strife to strengthen; and to this end nothing will conduce more than a knowledge of pathology.

The morbid processes to which the spinal cord is subject are, in the main, (1) functional; (2) nutritional; (3) anæmic and hyperæmic; (4) hæmorrhagic; (5) neoplasmic; (6) inflammatory; (7) degenerative. If we exclude hæmorrhage of the cord—an event of rare occurrence—and neoplasms, since in the cord they are similar to what they are elsewhere in the body, we are confronted with a remaining array of pathological states which are more or less interwoven. We may, for the present, with most show of reason, at once exclude from a too serious attention anæmia and hyperæmia of the cord. But when it comes to a sharp line of differentiation between the functional, the nutritional, the inflammatory, and the degenerative processes, we are not upon positive ground, even when we confine ourselves to the evidence of changes afforded by the microscope. The microscope furnishes no evidence of those finer molecular disturbances which we feel little doubt precede its actual revelations, and whose existence we are forced to accept by reason of the symptoms presented. It is, therefore, necessary to include in our classification nutritional diseases. But since a disturbance of nutrition necessarily involves a disturbance of function, the nutritional and the functional morbid states, so far as our present knowledge extends, must necessarily overlap. There are, nevertheless, transitory disturbances of function, often of a reflex nature, as in reflex spasm, or due to toxic agencies which necessitate the recognition of strictly functional diseases.

Again, a disturbance of function undoubtedly sets up in time disturbance of nutrition, and this latter may, in its turn, set up structural change. Prolonged irritation of a given peripheral sensory area may establish a myelitis in that part of the cord which is in direct relation with the stimulated afferent nerves. In short, every act of overfunction, in the cord as elsewhere, may be attended with an increased supply of blood, congestion, and consequent inflammation. And if, in these and in similar instances, the cell suffer impairment, the fibre, in its turn, suffers correspondingly, for the nutrition of the fibre depends upon that of its connected cell. We may, therefore, have all grades of functional and nutritional impairment of the cell and of its fibre accompanied by a corresponding symptom picture of disease, up to the final destruction of the cell and the associate degeneration of the fibre known as secondary or "Wallerian" degeneration.

In these functional and nutritional diseases of the cord electricity acts either directly upon the impaired cells or affects them indirectly by their afferent pathways. The diseases themselves will be referred to more in detail in the section upon "Special Electro-therapeutics."

Inflammation and degeneration of structural elements of the cord constitute by far the most familiar and the most typical diseases of this organ. The nerve-elements and their imbedding connective tissue and neuroglia are the tissues attacked. Meningitis and arterial sclerosis may be left out of consideration for the present, since the morbid processes

involved in them do not differ in the cord from the same processes taking place elsewhere in the body.

A primary distinction between these two important processes is that in inflammations the process begins outside of the nerve-elements, namely, in the connective tissue, and only involves the nervous substance secondarily, while the degenerations begin in the nerve-elements primarily and affect the imbedding tissue secondarily. This distinction cannot in all instances be satisfactorily maintained, as would be expected, in the absence of definite knowledge as to the ultimate nature of the initial process in either tissue.

The same distinction exists as regards the nerves. In isolated neuritis the primary affection is of the interstitial connective tissue and the nerve-fibre is affected secondarily, while in symmetrical or multiple neuritis the nerve-substance itself is the first to suffer.

A fixed line of demarkation between the two kinds of onset of the two processes cannot, in all instances, be drawn. In both the cord and the nerves the process, if outside of the nerve-elements, is termed interstitial or adventitial; if inside, it is termed parenchymatous. When beginning in the nerve-elements, the term parenchymatous inflammation is often used. But that inflammation, as now understood, attacks the nerve-substance itself is open to doubt; though there is no doubt that both in polyneuritis and in primary and secondary degenerations of the cord the initial process begins in the nerve-substance itself, and thus the connective-tissue proliferation is secondary to it. It is, apparently, the use of the word *inflammation*, as applied to the parenchymatous process, which causes confusion.

Inflammation of the adventitial elements of the cord is present in (1) acute, subacute, and chronic myelitis; (2) compression myelitis; (3) anterior poliomyelitis or atrophic spinal paralysis; (4) insular sclerosis; while degeneration of the nerve-elements gives rise to *primary degenerations*, viz., (1) progressive muscular atrophy, anterior cornua, and anterior-root fibres; (2) amyotrophic lateral sclerosis, modified type of the above; (3) locomotor ataxy, posterior columns and posterior-root fibres; (4) spastic paraplegia or lateral sclerosis, pyramidal tracts; (5) combined sclerosis; and *secondary degenerations*, viz., (1) lateral descending, of cerebral origin; (2) ascending and descending, of spinal origin; (3) posterior ascending, of posterior-root origin.

But, whatever the order of attack, whether connective tissue or nerve-elements first, a common result ensues, known under the general term of sclerosis. The sclerotic or hardening process is generally believed to be of the same nature as the chronic fibroid processes which affect other parts of the body, and which, therefore, we must consider to be a hyperplasia of the connective tissue. Recent observations of Chaslin and others would, however, seem to show that the process in many instances was an increase in the neuroglia tissue, which, in common

with connective tissue, forms the matrix of the spinal nervous substance. We should, in case these observations are established, refer to the neuroglia sclerosis. The term *sclerosis* is, however, most commonly applied to the primary and secondary degenerations. Insular sclerosis, on the other hand, is an instance of the primary process occurring in the interstitial connective tissue.

The general lesson which electrotherapy may learn from this brief survey of the nature of the pathological processes taking place in the nerve-elements and their matrix is that, on the whole, it has to deal with a chronic fibroid process. As to the mode of onset of this process, we have seen that it may begin either outside of the nerve-substance itself (interstitial) or be set up by an initial process within it (parenchymatous). It follows that, in those diseases of the spinal cord in which the beginnings of disease are in the connective tissue,—in which they are, namely, inflammatory,—treatment must be directed with a view of arresting the active process in this tissue. Such general principles of electrotherapy as apply to the treatment of the acute, subacute, and chronic fibroid processes elsewhere in the body will likewise be applicable here.

But, in the parenchymatous degenerations, viz., the primary and secondary degenerations of the cord, other considerations must have weight. In them the nerve or its cell suffers all degrees of structural destruction up to actual death, with an associate increase of connective tissue. The sclerotic process is an active one, not one of decay. In an extreme instance, as in secondary degeneration, after complete section of a nerve, the internodal nuclei increase in size, their protoplasm increases and becomes granular and compresses the myelin, separating it into small fragments, which are soon absorbed, leaving the mere sheath of the nerve. *Pari passu*, the activity of the nutrition of the connective tissue increases, and the final stage of sclerosis is reached. But the determining cause of what has taken place is the solution of continuity in the axis-cylinder, or, what would produce the same effect, the destruction of its nerve-cell. Atrophy of the cell or its axis-cylinder and hypertrophy of its imbedding matrix are synchronous events. Nutrition, which is in abeyance in the former, is in a high degree of activity in the latter. There is evidently an interdependence of nutritional life between the two, for, the more rapid the loss of vitality of the nerve-elements, the more rapid the adventitial growth of the matrix. Ranvier, as quoted by Gowers, has pointed out "that the destructive growth of the protoplasm which follows loss of function in the axis-cylinder suggests that normally its function restrains the vital energy of the cell-elements."

Since, then, the initial process of decay in primary and secondary degenerations of the cord (and in polyneuritis) is established, either in the axis-cylinder or in their ganglionic cells, the effort of treatment by electricity must necessarily be expended upon an attempt to arrest a decay, in contradistinction to an active hyperplastic process, as in

the so-called inflammations or interstitial types of cord (and nerve) disease.

What is the cause and the nature of this decay, and will electricity arrest it? Two questions easy to propound, and impossible, in the present state of our knowledge, to answer. The nature of the decay in secondary degenerations is more obvious than in the primary degenerations, or system diseases. The interrupted axis-cylinder swells throughout its entire length and suffers granular decomposition, while the myelin sheath, as we have seen, is broken up by an active process beginning in its nuclei and their protoplasm. The cause of the destruction of the fibre must, then, be sought for at the seat of the interruption of the continuity of the axis-cylinder, or at the impaired and injured ganglionic cell; and, so far as concern any hope of palliating or arresting the progress of such degenerations by electricity, treatment must be carefully localized to the original seat of the disease. It may also with advantage be secondarily directed to the disabled fibres and strands, and to their peripheral distribution, whether motor or sensory In effecting a localized treatment of this nature, the structure and the functions of the spinal cord must be kept in mind. So far as regards the motor pathway from the cortex of the brain to the muscles (descending degenerations of cerebral or spinal origin), it will greatly aid the practitioner to recall the division of this path, as mentioned, into cerebro-spinal and spino-muscular segments; the former beginning at the cortex and ending in the anterior cornu, the latter beginning in the cornu and ending in the muscle.

An illustrative type of disease of the cerebro-spinal segment is lateral sclerosis, or spastic paraplegia; and of the spino-muscular segment, progressive muscular atrophy. In like manner locomotor ataxy is a type of disease of the sensory elements of the cord, and its treatment by electricity must be guided by a due recognition of the locality and distribution of that part of the structure of the cord, its roots and and its nerves, which are the seat of sensory function. Beginning with these typical diseases of the cord, their various combinations in other forms of spinal disease are more easily recognized, and their localized treatment by electricity facilitated.

The nature and the cause of the decay of the nerve-elements in primary degenerations, or, as they are often termed, primary scleroses, —many of them also known as "system" diseases,—have been the subject of much speculation. It adds little to our information to say that there is an initial failure of nutrition in the parts affected; though from this point of view it would be most natural to expect benefit from electricity, since this agency, of all the natural forces, is the only one which traverses the tissues to their innermost depths and excites their irritability, whether protoplasmic, as in the individual cell, or organic, as in nerve- and muscle- structure. In favor of a simple failure of nutrition of the

axis-cylinder is the general fact that the farther removed it is from its "trophic" cell, the less its vitality and power of resistance against morbid influences. And since it is an actual prolongation of its ganglionic cell,—is, in fact, in structure and function, a part of that cell,—its vitality suffers in ratio with that of the cell. For these reasons electrical treatment must be most obviously directed to the nervous centres, either directly or indirectly, by afferent pathways, whether these centres are primarily the seat of disease or not.

In line with the nutritional view is the obvious fact that living organisms, whether vegetable or animal, are often not originally endowed with sufficient vitality to withstand the wear and tear of living, in which case some one tissue first suffers decay. This is probably the case in a well-known hereditary sclerosis like Friedreich's ataxy, and, in a lesser degree, in other primary scleroses.

It is undoubtedly true that cord diseases, otherwise progressive, are frequently arrested in their progress by electricity judiciously administered. The same arrest may occur spontaneously or by reason of other measures, particularly such as relate to an improvement of the general nutrition of the patient. For this reason general electrization as well as local is indicated, upon the supposition that the parenchymatous degeneration is due to a lowered vitality of the cell and its fibre.

Toxic agencies have an undoubted influence in causing primary degenerations, which may continue even after the elimination of the cause. Alcohol, lead, ergot, and the *Lathyrus cicera* produce this effect. Toxic substances formed within the body in the course of infectious disease may also have the same effect. The human body continuously produces toxic substances. Fatigue, overexertion, and chill lead to imperfect metabolism, with the formation of regressive products. Besides the familiar auto-intoxications due to uric acid and biliary substances there has been observed acid, aromatic, and other auto-intoxications. Albertoni names peptoxin, organic bases (leucomaines, ptomaines), products of the aromatic series (indol, skatol, phenol, etc.), sebacic acids, ammonia, methan, hydrosulphuric acid, and acetone as known substances which may act as auto-intoxicants. The aromatic substances in particular produce a neuro-paralytic effect.

The entire field of microbic affections, with its attendant chemical poisons, has yet to be investigated in its relations to producing nerve disease. Thus far no specific microbe has been discovered which could have even a remote relation to nerve-inflammations and degenerations. If importance can be attached to the idea of a toxic etiology of nerve-degenerations, it becomes a matter of legitimate surmise as to how electricity can modify or prevent the noxious influence of the toxic agency; since formed in the interior of tissues, this must be of anaërobic origin. The effect of oxygenation of the tissues, therefore, at once becomes a question of prime importance. To attain this end some available portion

of the vasomotor mechanism may be excited into activity, producing an increased blood-flow and a consequent increased oxygenation. d'Arsonval has experimentally established the important fact that a sinusoidal current of low frequency of alternation increases the respiratory circulation to the extent that the amount of oxygen consumed is increased by about 50 per cent., with a corresponding increase of urea, carbonic acid, and other final products.

As has been pointed out, for all purposes essential to the present presentation of the subject, the diseases of the cord may be included under the classifications of inflammations or of degenerations. Granting this, in its simplicity, we still should inquire, if we hope to intelligently apply any therapeutic measure, for the real cause of the inflammation or of the degeneration. And since at this point pathology leaves us without information, we are more than justified in turning to bacteriology for that aid in this instance which that branch of study has so brilliantly contributed to many other branches of medicine. Although at present the bacterial origin of these conditions is no more than a surmise, we may, however, devote a few words to the line of thought. As regards the inflammatory processes in nerve-tissue, every inflammation demands an irritant and the reaction to this irritant takes place in the connective tissue, the blood-vessels, the blood, and the lymphatics.

General pathology teaches us that the usual irritant which precedes inflammation is a microbe or the chemical products of microbic life. We may also possibly add to this causation of inflammation certain diathetic irritants due to perverted metabolism and perverted glandular action. In short, and roughly speaking, a toxin is the cause of the trouble.

Again, there is a large and important number of diseases of the cord which are simply degenerations, as, for instance, progressive muscular atrophy and the myopathies in general and locomotor ataxy. Here, too, we are at a loss to account for the degeneration. We merely know that the nerve-cell dies, and in this case, where there is no inflammatory reaction of connective tissue or blood-vessel, as well as where the reaction exists, the trend of modern thought would lead us toward seeking a toxic causation. What more natural than that the nerve-cell, bathed in a fluid toxic to its nutrition and life, should die out? The relation of syphilis to locomotor ataxy would be a case in point.

At the same time, to adopt the toxic theory would require us to concede that in many instances of disease the defensive power—that is to say, the resisting power of the cell to attack—was lowered. Such a concession almost goes without saying. And it seems equally clear that electricity restores this defensive power to tissues.

As has been said, the toxic causation of spinal-cord diseases is not established, but it should at least be borne in mind; and our therapeutic efforts may find expression in three distinct directions:—

1. To empirically combat, on the basis of clinical experience, a noso-

logical entity,—say, locomotor ataxy or myelitis. 2. To combat an inflammation or a degeneration. 3. To combat a toxic influence which we believe to be the ultimate cause of disease.

It need not scarcely be remarked that the latter course would be by far the most satisfactory. It opens out to one who makes a careful study of the effect of electricity upon living animal tissue a most inviting field of research. The facts of electrolysis or chemical decomposition in the intra-polar region are undisputed. The parts mainly affected by chemical action are those richest in salts. The salts in solution convey the current, suffer chemical action, which in turn sets up a biological change. It is at the biological effect that modern electro-therapeutics pauses with uncertain step. That it is produced is certain. When a current has traversed a tissue a change in its microscopical structure and its molecular condition has been set up which endures long after the current ceases. This is the effect which the electro-therapeutist of the future must harness to serve his purpose to cure. It is an effect which may yet be brought into important relation to the life-history of the microbe, to the degree of virulence of the microbic chemical products, or to the defensive power of antitoxins and the cells themselves.

The pathway to work is upon the above lines; since in the absence of a positive pathology the field is open to any reasonable pathological hypothesis at the stage when structural disintegration has occurred; but at an early stage, while the affected tissue is yet capable of responding to its manifold action. And it is probable that just in so far as a diagnosis can be made early, in just so far as the nature of the disease is ascertained, just to that extent and in that ratio will the benefits to be derived from the rational employment of electricity increase and be rated at a higher value.

Finally, whatever the ultimate nature of the pathological processes incident to the nerve-elements of the spinal cord may be, there can be no doubt that electricity, intelligently employed, has an influence upon their modification, control, and arrest.

The treatment of diseases of the cord is by no means exhaustive if confined to it alone. It has already been pointed out that the in-going pathways of the sensory nerves distributed to the periphery of the human body offer a means of affecting the nerve-elements of the cord, oftentimes quite as effective as direct electrization. But, in addition to this reason for giving attention to the spinal nerves, there exists the further consideration that both the nerves themselves, their end-organs, and the tissues into which they merge by molecular continuity or by contact, suffer alterations by reason of the central disease in nutrition, and consequently in structure and in function; they, therefore, also require treatment at the same time that the cord itself is treated centrally. And not only must the nerves be taken into account, but also the upward nervous extensions from the cord, even to the cortex. For the cord is but one of a

series of ganglionic centres, and is connected by fibres and strands with the brain-axis, the basal ganglia, and the cortex above and the peripheral terminations below. As a centre it offers a mechanism for reflex action and for the control of the sympathetic system, the blood-vessels, rectum, and the bladder, and the nutrition of the parts to which its nerves are distributed. As a pathway it is traversed by motor impulses from the brain and sensory impulses to it. From this stand-point the importance of a pathological localization of the parts affected in a given cord disease is self-evident. In no other manner can the electric current be localized to affected parts.

The wide territory over which the pathological state must be pursued in treatment is seen in a disease like progressive muscular atrophy. While the salient feature is a slow wasting of the muscles, the cause of the atrophy is due to a degeneration of cells in the anterior cornua; the motor-nerve fibres which arise at the cornua and proceed to the muscles also degenerate, while at the same time there may also exist a degeneration of the pyramidal tracts in the cord traceable even to the cortex, with bulbar and other symptoms of disease at a higher level than that of the cord. Indeed, now that the identity of multiple neuritis is recognized, we must be prepared to admit that disease of the cord and disease of nerves cannot be so accurately differentiated as was formerly thought possible. A parenchymatous multiple neuritis alone may give rise to symptoms which not long since were supposed to be wholly spinal.

The nature of the lesion in the nerves and their distribution varies with the nature of the lesion in the cord, whether acute or chronic, whether in motor or sensory centres, etc. Acute inflammations produce intense nutritional changes, while chronic degenerations produce changes not apparently proportional to loss of function of the central parts.

Changes of nutrition may be chiefly observed in the skin, bones, joints, cellular tissue, and the muscles. In general, if the motor nerves are affected the muscles suffer; if the sensory nerves, the skin and other tissue-elements in which they terminate. In their treatment by electricity the same guiding principles hold good as apply to the treatment of the central lesion, regarding them as an actual structural continuation of the impaired centre upon the state of whose nutrition their nutrition depends. The same may be said of the muscles.

In both nerve and muscle, arrest of disease and regeneration of tissue can only take place in ratio with improvement at their trophic centres; but local treatment hastens the peripheral repair, exercises the muscle, and produces a considerable degree of functional restoration of afferent impulses. The return of sensation in hemiplegias of some considerable duration, as well as the abolition of anæsthetic and analgesic areas in locomotor ataxy, after treatment by electricity, are examples of sensory improvement from peripheral treatment. It seems that by stimulation by electricity the afferent pathways become more open to in going

impulses, both of common sensibility and of touch, temperature, and pain. This may be experimentally demonstrated in cases of locomotor ataxy, the typical cord disease of impairment of sensory function, and affords a most suggestive basis of treatment. In cases where there is almost complete abolition of sensibility to contact, temperature, pain, and muscular sense, a brief treatment by franklinic sparks restores in a remarkable manner, and in a uniform order of succession, these various sensations.

It is, therefore, desirable, both on physiological and on pathological grounds, to treat the peripheral results as well as the central lesion, regarding the two as both structurally and functionally integral. Within the scope of peripheral and local and general treatment will then naturally fall paralyses, atrophies, spasms, and contractures of the muscles, degenerations of the nerves, and inflammations of their adventitia, as well as sensory nutritional alterations. To neglect this aspect of treatment is like guarding the front and leaving the rear exposed. To pursue this plan rigidly in practice is to obey, on a broad basis, that most important maxim in electro-therapeutics,—to apply the agency counteracting to disease *in loco morbi.*

II. The Mode of Manifestation of Electric Energy Employed, viz., the Kind of Current.

Electricity is at present known to us only through certain manifestations of energy. It is these manifestations or phenomena which the physician summons to his aid to treat disease. It has too often been assumed that electricity is an entity, a subtle thing to be turned into the human being, there to seek out and throttle disease, or, at least, if such were not its action, to supply "a long-felt want." Much of this superstition, which still clings to electro-therapeutics, is based upon a vague idea that, since electricity and vital force are equally mysterious and marvelous, they must be identical, and, therefore, "Electricity is Life," or that nerve energy and electric energy are one and the same thing.

It will conduce to a clear perception of the purpose for which an electric treatment is administered to keep in mind the fundamental conception that the administration represents the impact upon the tissue protoplasm of an outside energy akin, for instance, to light and heat, but differing in its rate of motion or vibration and in its quality and power; to adopt, in brief, the modern view that electricity, in so far as can be decided to-day, is a manifestation of ether motion. From this point of view we may conceive of an ordinary treatment by our ordinary electric appliances, and causing the familiar nerve and muscle responses to be increased in its rate of vibration up to the velocity of light, with the result that the effect upon living tissue would then be the same, or at least as genial and bearable, as light itself. This, in effect, is what

modern experiment would seem to indicate may be possible; for, by aid of specially-constructed apparatus the frequency of the alternations of the current may be increased to a point where, even with the enormous electro-motive force of from 100,000 to 1,500,000 volts, a human being may be subjected to its entire effect without suffering the least harm, or indeed being aware of any muscular contractions or of pain.

The point of view, therefore, from which to work in electrotherapy is not what will be the effect of an introduced entity, like a drug or medicine, but what will be the effect of the electric energy brought to bear upon normal and diseased tissue.

With this brief reference to the nature of the curative agency employed, it still remains to point out its varieties,—in other words, the kind of current to be used. Long usage sanctions, in medicine, the division into galvanic, faradic, and franklinic electricity, and convenience suggests, at least for the present, the retention of these terms. This classification is, however, it would seem, a most unfortunate one, since it has led to invidious rivalry as to the superior merits of one or the other upon the basis of differences supposed to be peculiar to each, but in fact shared in greater or lesser degree by all. The classification is founded upon the sources of electric energy, and not upon its nature. A simpler classification, it would seem to the writer, at least for medical purposes, would be to discriminate as to the nature of the electric treatment to be administered, by referring to its electro-motive force or voltage, its current-strength or ampèrage, and to the frequency of its interruptions, regard being paid to whether these permitted of alternating or intermitting currents. A prescription, for instance, written in the above terms, would indicate at a glance the mechanism by which it should be evoked; whether by the chemical action of cells, the movements of magnets and wire coils in relation to each other, or by friction and multiplication by induction.

From a general point of view, the science of electricity is divided by Dr. Oliver Lodge into four great branches. These four divisions are:—

(*a*) Electricity at rest, or static electricity,—including what is generally known as frictional or franklinic electricity.

(*b*) Electricity in locomotion, or current electricity,—including the continuous current, or galvanism; and the interrupted current, or faradism.

(*c*) Electricity in rotation, or magnetism.

(*d*) Electricity in vibration, or radiation; or the phenomena of light.

Of these four divisions, the second only comes especially within the scope of electrotherapy. For all electricity used medically is electricity in movement,—kinetic, or, as it is often termed in medical textbooks, dynamic electricity. This statement, at first glance, would seem to exclude that made of electric manifestation produced by frictional and influence machines, commonly termed franklinic. It does not, how-

ever, exclude, but includes it; not, indeed, in its static condition, or state of rest, but in its kinetic condition, or state of discharge, or flow.

We have no experience, in electrotherapy or in electrophysiology, of the action of electricity at rest upon living tissue. To obtain such an experience we must regard these tissues as dielectrics subjected to the stresses and strains of the electric charge. But they are, in the main, conductors, and as such serve to dissipate rather than retain an electric strain. The nearest strict approach to the action of electricity at rest upon the human body is seen in the franklinic "electric bath," where the patient is placed upon an insulated platform and is then positively or negatively charged from the electro-static machine. In this instance the patient represents an insulated electrolytic conductor. His electric charge varies with every oscillating surge of the machine and, moreover, continuously escapes to surrounding objects. Both its variations and its escapes are phenomena of flow or current. In any event the effects of this electric bath are incomparably surpassed by the spark forms of administration.

It follows therefore that, though by usage we refer to treatment by statical electricity, we are in reality obtaining our effects by electricity as truly dynamic, kinetic, and in current-form, as would be the case in employing the current from voltaic cells or induction machines.

Frictional electricity released from its state of rest and becoming kinetic produces nerve excitations and muscular contractions as vigorously as does galvanism or faradism; and this though the two forms of electric manifestations are at extremes as regards current-strength and electro-motive force. In fact, in the absence of definite knowledge of the mechanism by which the nerve excitations and muscular contractions are brought about, it is impossible to know whether to attribute the result to electro-motive force or to current-strength, or to both combined. D'Arsonval attributes the excitation to the difference of potential and its variations, while from another point of view the current-strength may be the important element.

At all events, enough has been said to justify the inclusion, on other grounds than those of pure empiricism, of franklinism within the justifiable means for the electric treatment of disease,—a position necessary at this time to make clear owing to the prejudices of fashion or ignorance. It is often, for instance, stated that since static electricity resides upon the surface of charged bodies, its influence is superficial and cannot affect deeper parts. Not only is this statement disproven by actual experiment, but it is, as we have just seen, untenable in the light of electro-physics. Static electricity, as has just been pointed out, when put to medical use, becomes kinetic electricity. Its strain is dissipated along and within conductors (the human tissues, for instance) with the same facility as currents having a different ratio of electro-motive force or ampères. If there were any reservation to be made in thus putting the

statement, it would be that possibly the rapid oscillatory nature of the discharge might fail to afford time for the impulses to sink into conductors. Granting this, its high electro-motive force would compensate for the lack of time.

It is obvious, from what has been said, that the physician cannot limit himself to any one of the varieties of the manifestation of electric energy indicated by the terms galvanism, faradism, and franklinism, since these terms represent merely an artificial distinction, and since they are, in greater or less degree, mutually interchangeable in all of their important properties. A voltaic battery, an induction coil, and a franklinic machine must, therefore, constitute a part of his necessary outfit.

Concerning these chemical or mechanical means of causing electric energy to be exhibited, details must be sought for in other parts of this work, since in this section only such points will be brought forward as may serve, it is hoped, to place the treatment of spinal-cord diseases upon a broad and general basis subject to expansion and change rather than upon the narrow basis of limited procedures.

Galvanism; the Voltaic Battery.—Any good cell may be used, preferably connected in series, as is usual, to form the battery. As regards the choice of cell, the claim that, at a given value of current-strength, certain cells cause more chemical action than others is unworthy of attention. Scarcely less worthy of attention, except that it is often maintained by high authorities, is the contention that at a given current-strength the pain produced at the electrodes is greater in direct ratio to the electro-motive force which produces the current—that, for instance, 10 milliampères received from a few cells without the intercalated resistance of a rheostat is far less painful than 10 milliampères received through a rheostat requiring, say, 60 or more Leclanché cells to produce the current-strength named. Obviously a milliampère is a milliampère, whatever may be the ratio of the electro-motive force and of the resistance which governs the rate of flow or ampères.

It is assumed that a good rheostat and a milliampèremeter are always in circuit. Of equal importance as the milliampèremeter is a record of the surface-area of the electrodes. The absolute current-strength employed gives but little information as to the actual current traversing the tissue. We must also know the current-density; that is to say, the actual rate of flow of the current passing into and through tissues per unit area of the surface traversed at the point where the electrodes are applied. The superficial area of the electrodes may be conveniently expressed either in centimetres or in inches. The density of the current per unit area is of especial importance to an accurate record in treating diseases of the cord where large spinal electrodes are used. We will suppose that the treatment is by the unipolar method, and that the active electrode laid over the course of the spinal cord is 18 x 2 inches = 36 square inches. With a very large indifferent elec-

trode the reading of the milliampèremeter may run as high as 50 to 100 milliampères without causing an eschar in the patient's skin or otherwise causing him inconvenience. To record that the reading from the needle was 72 milliampères, for instance, gives no clue to what current-strength any given portion of the cord has been subjected to. But if it is known that the surface-area of the active electrode is thirty-six square inches, we easily compute that each inch-unit of tissue treated has been traversed by 2 milliampères. In this manner results of different observers may be compared and repeated. The same reasoning holds good for the bipolar methods and for both stabile and labile treatments.

From the voltaic battery is directly derived a continuous current, an intermitting or interrupted current, and an alternating current (voltaic alternatives). The differences in the effect upon living tissue of these varieties of the galvanic current require more extended investigation than is ordinarily accorded to them, and more than our present scheme of presentation will allow of. If we broadly classify the effects upon tissue into (1) physiological and (2) chemical or physical, we see that we have, in the above modifications, the means of producing both of these effects. Whether we obtain one or the other depends upon the duration of the current-flow. Interruption—viz, brief duration of flow—produces physiological effects or excitation of excitable tissues, while continued flow produces the chemical and physical effects known as electrolysis and cataphoresis. If, however, the interruptions produce a succession of currents in the same direction, the total amount of chemical and physical effects represented by equal quantities of electricity will be equal, in which case a treatment by an intermitting current combines the two effects. The continuous current avoids the physiological, but produces the chemical and physical. The alternating current produces the physiological effects in the highest degree, and, at least theoretically, should leave no resultant product of chemical decomposition behind it, since its decompositions are no sooner effected than a recomposition ensues. And to the above must be added those profound alterations in the physiological function of nerve- and muscle- tissue produced by the continuous current. It has been demonstrated, for instance, that a continuous current passed for a brief time through the intact leg of a living frog lowers its excitability to the extent that, even at the end of a week, the electrized leg will require from ten to twelve times as great a stimulus as the unelectrized leg to produce the same degree of contraction. Moreover, the muscles of the leg through which the current has passed present profound and characteristic changes when examined microscopically.

Faradism; Induced Currents.—Since an induced current is necessarily an interrupted or varying current, its usefulness will be mainly confined to starting excitable tissues into activity, and as such, in diseases of the cord, is mostly employed in the treatment of nerves and

muscles affected consecutively to the primary lesion. By reason of its high electro-motive force, it may also be employed by introducing additional resistance, like starch-powder on a dry skin, to irritate the peripheral-nerve distribution, and thus indirectly but decisively to affect given nerve-centres or even distant organs or parts by reflex action. Simple as, at first sight, the mechanism of an induction coil would seem to be, there is probably no mechanical electric device more complicated in its action or more capable, by modification of its parts, of affording a different resulting current. The crude induction coil of medicine has now merged into the "transformer" so essential to the distribution of electricity for light and power; and, in the immense study that has been given to it in this new relation, we may realize the difficulties of its comprehension by the physician. The main contention which is now occupying the medical mind interested in the use of induction currents is as to the relative merits of the "fine" and the "coarse" wire coil,—a discussion which, it would seem, would at once cease if it were changed to read a "greater or less number of turns of wire" of the secondary coil. Other parts of the apparatus and the frequency of interruption being agreed upon, the greater or less number of turns of wire will produce for medical purposes all that is implied in the question of fine or coarse wire and, at the same time, express the facts of the case. At all events, it is important to adopt a standard medical induction coil.

Franklinism—"*Statical*" *Electricity.*—Cumbersome and objectionable as the influence machine may be, from the respective points of view of convenience of use and display of apparatus, it is, nevertheless, essential to one who proposes to concede to the patient all the benefits that may be derived from treatment by electricity. Revived in this country by the writer, in the wake of its brilliant revival in France by Professor Charcot and Dr. Arthuis, franklinism steadily wins its way, though against strenuous opposition, to approval. Its physical phenomena stand forth in striking contrast to those of galvanism and faradism, and in no less striking contrast are its physiological effects. Its physical peculiarities are its high electro-motive force, with correspondingly low current-strength; the oscillatory or alternating nature of its current; and its disruptive discharge, in the shape of a single long spark or in the shape of innumerable fine sparks. Its physiological effects, corresponding to high electro-motive force and alternations, are the excitation of nerve and muscle irritability, provoking contractions of muscle-tissue, as do the galvanic and the faradic currents; corresponding to its long spark, a high degree of mechanical perturbation of tissue; and, corresponding to its fine spark, revulsive effects of great importance. Furthermore, franklinization by sparks increases the pulse-rate, modifies the temperature from one-fourth to two degrees, and increases the excretion of urea. These and other effects will be referred to in more detail later on. But it must not be believed that these effects

can be obtained in a degree worthy of the least consideration from small machines. They are mere toys, and do no real work. The physician deceives himself, or is the dupe of the manufacturer, if he is content with them.

Granting equal perfection in running-gear, the machine that requires the most expenditure of mechanical energy to actuate it will give forth for use the most electrical energy, for the apparatus represents a simple transformation of mechanical into electrical energy. Since the electromotive force or striking distance of the spark is determined by the radius of the revolving glass plate, a long spark may be obtained from a single plate; but, again, since the quantity of electricity is determined by the number of plates, a considerable number must be used to obtain a thick or quantity spark. The spark must be both thick and long, whether used *per se* or in its representative forms of spray or "electric bath," and, as a consequence, the machine must be built up of a large number of plates of large diameter. From four to eight in number and from twenty-eight inches upward in diameter would seem to fulfill present requirements. The use of Leyden jars with small machines will, of course, yield a long and a quantity spark, but the infrequency of the spark reduces its practical value to *nil.* In an experience of more than ten years' use of franklinization, in private practice and in free clinics, where its effects could be rigorously observed, the writer has found that curative results are, with but immaterial reservations, obtained from powerful machines and powerful administrations.

The "Static Induced Current."—Medical treatment by franklinic electricity, up to 1880, had always been confined to the spark or some modification of the disruptive discharge, in the shape of spray or breeze. At that time the writer discovered and first published [1] an account of a method of obtaining from influence machines a current which, for want of a better comparison, was likened to a faradic current.

This current is produced by the aid of condensers or Leyden jars put into the circuit. Leyden jars had been habitually used to intensify the spark, but never as a source of a continuously-interrupted current. The frequency of the interruptions and the difference of potential of the individual impulses were determined by the relative approximation and consequent length of spark between the discharging rods. Even if no actual condensers are used, the parts of the machine in a state of positive and negative charge suffice, when a series of small sparks jump across from rod to rod, to produce this franklinic current in a circuit which is a derived circuit from one pole to the other of the machine. The patient intercalated in this derived circuit receives a current of great power and peculiar properties. Nothing similar can be obtained from faradism or galvanism. This static induced current is especially applicable to diseases of the cord. Its method of application will be described later on.

[1] New York Academy of Medicine, March 3, 1881; New York Medical Record, April 2, 1881.

III. The Action of Electric Energy upon Living Tissue.

Of no less importance than a pathological basis is an equally precise knowledge, so far as is possible, of the action of electricity upon living tissue. With these two data well in hand, the clinical result to be expected may be predicated with a fair degree of certainty, and success or failure may be charged up to specific data rather than be blindly attributed to electricity in general.

The cord and spinal nerves cannot be intelligently treated by electricity without a brief consideration of the action of the agency employed. Fuller details must be sought for elsewhere in this work.

The human body, regarded as a recipient of electric currents, must be considered in the double light of a living tissue and of a mass of heterogeneous electrolytes. At first sight, therefore, it might seem proper to divide its reactions to the electric stimulus into (1) physiological and (2) physical and chemical, but the chemical and physical effects cannot be eliminated with sufficient exactness from the physiological to warrant such a division. Not only is it probable that the physiological reactions depend upon the chemico-physical, but it is certain that the polar and intra-polar electrolytic action of continuous currents produce profound modifications of structure and function in nerve and muscle, enduring for weeks after a single electrization.

We must content ourselves, therefore, with a simple enumeration of the action of currents upon tissue. They are, briefly :—

1. *Electrical Excitation—" Irritation," or Stimulation.*—The simplest forms of organized living protoplasm, vegetable or animal, are excitable by electricity. Thus, each tissue-element of the body, composed of cells capable of motion, undergoes a sort of interior massage, while all have their specific function excited. Electric energy undergoes transformation into specific tissue energy. Varying currents are the most efficacious in producing this result; though a constant current may also create effects similar, but differing in quality and degree.

The nerve- and the muscle- tissues are those to which most attention has been directed.

The laws of normal reaction of nerve and muscle, and their abnormal reaction when undergoing degeneration (reaction of degeneration of Erb), as well as the reactions of the sensory nerves and nerves of special sense, will be found fully detailed in other parts of this work. One modified form of electrical irritability which may be mentioned here is termed " electrotonus."

2. *Electrotonus.*—This state is due to the passage of a continuous current along and through the nerves, producing alterations in its irritability and its conductivity. It is often denied that this action, demonstrable with perfect accuracy on the naked nerve, can be obtained from the nerve *in situ*, in the human body. We have only to recall that the

body is a heterogeneous electrolyte, and also the consequent phenomena of internal polarization, to enable us to admit that a polar electrotonic effect upon the nerve is possible.

3. *Vasomotor.*—At both poles there is a primary contraction of the arterioles which quickly at the negative pole and less quickly at the positive pole becomes dilatation. Detailed description of vasomotor effects due to stimulation of the spinal cord, spinal nerves, and the sympathetic nerve must be sought for elsewhere.

4. *Electrolytic.*—Since all conduction of electric currents in the human body is electrolytic and no current, however small, can pass without its due quota of electrolytic decomposition, it follows that this action is the most fundamental one in electrotherapy. To it we must doubtless attribute those chemical, structural, and functional changes in the intra-polar region demonstrable by actual experiment upon living animals, and yet often denied. It is apparently forgotten, in making this denial, that, although intra-polar electrolytic action itself cannot be demonstrated, yet its results upon tissues which it traverses can be, both physically and microscopically.

The phenomenon of internal polarization in a non-homogeneous electrolyte like the muscle demonstrates the existence of an intra-polar effect of the continuous current. Volta long ago observed that if a continuous current was passed for some time through a muscle it lost its excitability, but that if the current was reversed the muscle again became excitable. Stewart and G. Weiss have established the facts of internal polarization, and the latter has shown that in causing the current to pass from one foot to the other of a frog the entire body is the seat of a counter-electromotive force of about one-fifth volt, while from hand to hand of the human body about the same voltage was observed. Thus the continuous current traversing a muscle produces two intra-polar effects,—diminution of its contractility and a counter-electro-motive force due to electrolytic action; intra-polar electrolysis must, therefore, be accepted. Weiss has likewise demonstrated upon the frog marked microscopic changes in the muscle subjected to electrolytic action.

5. *Cataphoric Action.*—Excluding physiological action, next to the electrolytic in importance is, doubtless, the cataphoric action of the current. By cataphoresis is meant not its restricted use in conveying medicines through the skin or mucous membrane, but the general law of the flow of fluids in the direction of the current from the positive to the negative pole. In this manner a desiccatory action is set up at one pole and a liquefying action at the other. An action as broad and as definite as this has its obvious bearings upon the treatment of disease.

6. *Mechanical Action.*—In addition to a cataphoric action, which may be partly mechanical and partly electrolytic, there exists a simple mechanical disturbance or displacement of tissue. This is pre-eminently characteristic of the long spark of franklinic electricity, where this

action may be pushed even to ecchymosis or dermatitis; theoretically, also, every electro-static impulse, whether of faradism or franklinism, must produce its due share of strain in any tissue-element where this strain is not kinetically dissipated into current. The less electrolytic a tissue, therefore,—that is to say, the more it partakes of the nature of a dielectric,—the more susceptible it will be to the mechanical disturbance of electric strain or charge.

7. *Thermal Action.*—The thermal effects of currents of the current-strength used in medicine, though but slight, are important as indicative of the production of heat (*a*) by the resistance offered to the current by the passage of the current; (*b*) by the metabolic exchanges set up, especially in the contracting muscles; (*c*) by increase of the blood-circulation; (*d*) by stimulation of the thermic centre in the medulla. The heat produced by the first-mentioned means is inappreciable; by some one, or by a combination of the last three, the bodily temperature may be modified, according to the writer's observation, from one-fourth to two degrees.

8. *Nutritional or Trophic Action.*—It matters not whether the nutrition of the tissues is controlled by special trophic nerves or whether this control is exerted by the motor, sensory, and vasomotor nerves, the effect of stimulation of the nutritional centres and fibres is to affect the nutrition of the parts to which the nerves are distributed. That this effect is beneficial is established by the consensus of clinical experience. It is an effect obtainable both by local and by general electrization, but not equally by each kind of current, and, probably, not equally by each pole, though about the polar differences little is known. Franklinism, faradism, and galvanism all produce this effect, and with a relative superiority in the order named. General applications like the galvanic bath, general faradization, general franklinization, and d'Arsonval's sinusoidal current seem to be more efficacious in actual experience than any special methods. Seldom is a patient treated by any of these methods whose general health, weight, facial appearance, and feeling of well-being are not notably improved. And it is to this sort of result that improvement in spinal-cord diseases is to be often attributed, as well as to administrations directly localized to the affected centres.

9. *Action upon Dielectrics.*—Though not hitherto, so far as I know, taken into account, there must be an action of electricity upon the dielectric or non-conducting portions of living tissue. This action will depend upon the voltage of the electricity employed and upon variation in current-flow. The dielectric will be in a condition of electric stress, and exactly in ratio as the dielectric tissue or parts of tissue are better conductors the electric stress breaks down into current. It is a question primarily of inductive effects upon tissue, but not of induction, which is represented by the production of a current. The result is rather a strain, distortion, or partial displacement of the molecules of

the dielectric, and such an electric stress may evidently be set up by electro-magnetic discharges of induction coils or by the varying field of bodies charged electro-statically. Hence, we may take this influence into account, both as regards our medical induction coils as well as regards our electro-static machines, though it will be most marked in the latter.

10. "*Suggestion.*"—It has been claimed by Möbius that the therapeutic results attributed to electricity and electric procedures are in reality due to suggestion. Others before him had also put forth this theory to account for the otherwise to them inexplicable effects of franklinization. It is well to accord to suggestion full weight; if it be found that it produces the same results as electricity does, it will prove to be a most interesting alternative procedure. There can, at least, be no doubt that it plays the same part in electro-therapeutics as in all therapeutics; what this may be remains to be determined. Thus far "psychic influence," "faith cures," and "suggestion" lack an objective basis; such a basis, on the other hand, is familiar to us as regards electricity. In a living animal electrolyte like the human body electricity produces actual chemical decompositions, polar and intra-polar; it redistributes fluids by mechanical cataphoresis; it impoverishes tissues of their salts by electrolysis; it displaces tissue mechanically and electro-statically; and, as a result of its action upon tissue-elements, structural alterations are demonstrable, chemically and microscopically, and their function correspondingly modified.

There can be no doubt that the tissue itself is directly altered by the passage of the current, and that the therapeutic results attainable are due to this physical or chemical change. This is the basis of the physiological phenomena of electrical irritability in nerve and muscle; it is equally the basis in producing an alteration in a pathological process. Whether the alteration effected results beneficially or harmfully is another question. It is sufficient at this point to rest upon physics rather than upon psychics.

And even were we in want of a physical explanation, we should still be entitled to claim for electricity an intrinsic objective quality in its action as patent as that of mercury and other drugs, even though in the one instance as in the other we might not, as yet, be able to explain the nature of the process by which tissue changes were brought about.

In any event, true electrotherapy owes quite a debt of gratitude to Dr. Möbius for promulgating this theory of suggestion, which has stirred it to its very depths and placed it on the defensive. Electro-therapeutics has too long been the "catch all" bag, so to speak, for all incurable diseases, and likewise the bountiful cornucopia which has turned out an endless supply of miraculous cures. It is time that a halt should be called and an attempt be made to ascertain the true place of electricity in medicine.

11. *Metabolic Polarity.*—Starting upon the basis that the processes

of life in organized beings are chemical processes, and that such chemical affinities may, under conditions of circuit and voltaic arrangement of protoplasmic elements, give rise to currents of electricity as well as to heat, the writer has ventured the hypothesis[1] that both physiological and pathological chemism (metabolism) must exhibit a polarity which he has termed "metabolic polarity," and has proposed, as a basis of treatment, that a given polarity of disease have applied to it an extraneous battery polarity of the same or an opposite name in order to augment or diminish the chemical exchanges underlying it. And granting that the chief processes of living are katabolic or destructive, all metabolism should be initially electro-positive, as is the zinc or negative element in a voltaic cell.

It follows that when chemical exchanges—viz., metabolism—are excessive (*a*) a + pole will increase the excess, augment the disease; (*b*) a — pole will diminish the excess, diminish the disease; but if the chemical exchanges are under-active (*a*) a + pole will increase the under-activity; (*b*) a — pole decrease it. In over-activity of metabolism a — pole, in under-activity a + pole is palliative or curative. The theory is at present merely an hypothesis.

12. *Unknown Action.*—How arsenic, iron, mercury, iodide of potash, and many other drugs produce tissue change is unknown. It is equally reasonable to conclude that there is an unknown result upon the tissue due to the direct action of electric energy.

It is, of course, not always possible to confine an electrization to any one of the specific actions just enumerated; a near approach to selective action is afforded by the characteristic differences at the two electrodes, for there is scarcely one of these actions which does not present a polar quality. Hence the polar method.

But, as a rule, a special or at least a predominating action of the current can be employed to affect a given disease, or a combination of actions all harmoniously conducing to a therapeutic result may be arranged. The action of the current upon tissue-elements is, on the whole, tolerably clear. The chief hiatus in our knowledge is the ultimate result to the tissue. What change has taken place in the muscle by the simple passage of a continuous current that its irritability is ten times less than the untreated and corresponding muscle on the opposite side? What molecular changes have taken place in the electrotonic nerve? What is the mechanism by which electric energy becomes transformed into the energy characteristic of diverse tissues, as when a muscle contracts? It is these ultimate effects of the current upon tissue which open up a vista to a field of biological study yet almost a *terra incognita*. When biology has solved problems of this nature electro-therapeutics should be the most exact branch of therapeutic medicine.

[1] New York Medical Record, September 3, 1892.

IV. Methods of Application and Treatment of Special Diseases.

Prefatory to the technique of methods of application arises the very fundamental question of whether the electric current can reach the spinal cord. That both this organ and the brain are inaccessible to ordinary percutaneous galvanizations and faradizations has often been claimed, and as often disputed. It must be admitted that no very satisfactory proof that electricity does reach the brain and cord has been adduced. But, though experimental demonstration may be difficult to devise, it is, on the other hand, impossible, in the writer's opinion, to fairly state the question in such terms as to deny that the brain and cord are actually traversed by the current. Earlier objections were based upon the non-conducting properties of nervous tissue or of intervening tissues. But recently it has been claimed that the current fails to reach the cerebro-spinal axis, not because this axis is, in itself, of non-conducting material, but because the parts surrounding it, particularly the sanguineous and serous plexuses and the cerebro-spinal fluid, are better conductors than nerve-tissue, and therefore short-circuit, so to speak, the current around it. This claim is untenable.

It may first be remarked that the conduction of electricity in living bodies, owing to the nature of their constituents, is necessarily electrolytic, and that the brain and cord offer no break of continuity of electrolytes. According to the law of derived currents each component electrolyte of the heterogeneous mass which composes the human body will receive its due ratio of current. Blood, muscle, cerebro-spinal fluid, and nerve-tissue are all fairly good conductors of electricity; their conductivity, doubtless, depends upon their respective salinity. Turning to analyses of these respective electrolytes, we may find that, while the blood contains about two parts of salts out of a thousand, cerebro-spinal fluid and nerve-tissue contain over one part out of a thousand. A due and large ratio of current cannot therefore be denied to nerve-tissue. Furthermore, attributing to the blood the highest degree of conductivity, we have but to recall the dense distribution of capillary blood-vessels dipping down into the entire substance of the brain and cord from the pia mater to re-assure ourselves that just as the blood-stream permeates every portion of nerve-tissue in order to sustain its nutrition, so by the very same pathways the electric current finds its way to the same tissues to influence the same nutrition.

As to actual experiment, nothing has been added to our knowledge since Erb's observation that if the cathode is placed upon the upper lumbar vertebræ, powerful cathodic closure or change of polarity to the cathode will produce vigorous contractions of the muscles supplied by the sciatic nerve, thus proving that the current penetrated within the spinal canal. And little or nothing has been added to our knowledge

of the physiological effects of electrical currents upon the spinal cord since the same writer wrote that it was almost *nil.*

Even at this day it is not decided whether the spinal cord is excitable by direct stimulation, whether electrical or mechanical. The phenomena of motion and pain, attributed by some to stimulation of the anterior or posterior columns, are by others thought to be due to irritation of the corresponding roots, or, in the case of movements, also due to reflex action.

Diseases of the spinal cord may be treated by general, by local, or by peripheral electrization.

General electrizations may be carried out by the familiar methods of Beard and Rockwell, by means of the electric bath, with water, or by means of the franklinic electric bath and sparks. A general electric treatment is demanded when the purpose is to improve the entire nutrition of the patient, and thus to favorably influence the locally perverted nutrition of the diseased portion of the cord. Not enough importance, it seems to the writer, is attached to a general nutritional treatment.

Both the galvanic and faradic electric baths have afforded excellent results in the treatment of tabes and primary lateral sclerosis, and they are contra-indicated in no chronic nor subacute disease of the cord. Improvement in the health of the invalid is soon manifested; his appetite and assimilation of food are increased, and, if present as a part of his disease, constipation, sexual impairment, bladder troubles, spastic condition, anæsthetic and hyperæsthetic states ameliorate. The bath would seem to be a step in the right direction, of submitting the greatest possible area of the patient to a maximum quantity of electricity, for, by increasing the size of the electrodes, it reduces the current-density at the point of entry of the current, and increases the total current-strength employed. Taking into account the effect upon the peripheral nerves, the effect upon metabolism, and the very considerable local current to the affected part of the cord inseparable from the larger general flow, the electric bath is worthy of confidence, in spite of its unfortunate relegation to quack establishments, and in spite of its apparent contradiction to the axiom of Duchenne to treat disease strictly locally. Local treatment may at the same time be pursued.

In connection with the ordinary galvanic and faradic bath should be mentioned the recent procedure of Gautier and Larat, of conveying to the patient, by means of the water electrode of a similar bath, the sinusoidal current, as described by d'Arsonval, who claims that this current, thus administered, increases the metabolic exchanges to the extent that there is an increase of about 50 per cent. in the amount of oxygen consumed, and a corresponding increase of the urea and carbonic acid eliminated. Of equal, if not of greater, importance than the water bath is the franklinic electric bath. This form of electric treatment also greatly

increases the metabolic exchanges, as I have demonstrated, by a long series of experiments not yet published, upon the pulse, temperature, and urea excreted. The franklinic bath has the great convenience that it does not require the removal of the clothing.

To turn from general to local procedures, we are at once confronted with a complexity of methods. Referring for the moment particularly to a galvanic or continuous current, shall we employ a unipolar or a bipolar method, ascending or descending currents; and shall our applications be stabile or labile? We may at once exclude as obsolete a rigid attention to the direction of the current. The reasons for the direction method were based upon the physiological doctrines relating to the direction of the flow of nerve-impulses, while our aim should obviously be to combat pathological conditions. And even though we might claim that to influence the function may ultimately influence the structure of nerve-tissue, there is as yet no proof of this in relation to the practice of causing the electric current to flow either in the same or a contrary direction to the nerve-current.

But that there is a distinctive basis for the adoption of the polar method there can be no doubt. The opposite action of the continuous current at each pole upon living tissue, when carried to the extreme of surgical electrolysis with actual electro-chemical decomposition, is conclusive evidence. At and about the positive pole collect acid products, and at and about the negative alkaline products; and if the remaining intra-polar region be microscopically examined, structural changes peculiar to each polar nucleus will be found to shade off in degree toward the neutral central portions.

Lesser grades of polar action, as in the ordinary percutaneous treatments, unaccompanied by actual decomposition of tissue, but exhibiting, nevertheless, microscopic structural changes in muscle- and nerve- fibre, must, perforce, display similar polar distinctions of action, though they be less in degree. Admitting special polar characteristics (evidence of which will be found treated of elsewhere *in extenso* in this work), we must adopt a polar method, and in this case the electrodes will be placed in position by the unipolar method,—that is to say, the electrode whose special action is desired is placed in the nearest possible relation to the tissue to be affected, while the other electrode, constructed of large dimensions, in order to spread the current-strength employed over a large area, is placed at some remote part of the body. The large electrode is termed the indifferent electrode.

In contradistinction to this—the unipolar—is the bipolar method, where each electrode is of about the same size, and credited with its own specific polar action. Whether the current is stabile (both electrodes fixed) or labile (one fixed and the other moved about) is, apparently, not of much importance, except, perhaps, from the minor point of view that a labile electrode necessarily means a greater or less variation

in current-flow, and consequently adds to the customary action of a continuous current the physiological action of an interrupted current. It is obvious, then, that the writer declares himself in favor of the unipolar method. In fact, in the gynæcological operation so brilliantly initiated by Apostoli, and in surgical electrolysis, there can be but one opinion; but in percutaneous treatments, such as those of the spinal cord and of the nerves and muscles in connection with the cord, the subject required an attempt at justification. For even now there is but one classical reason for selecting one or the other electrode on given instances of cord, nerve, and muscle administrations, and that is that the positive pole possesses a sedative, while the negative pole possesses a stimulating, action. If this reason seem satisfactory to others, the writer would be unwilling to criticise it; it is founded upon the physiological phenomenon of electrotonus,—a condition admittedly difficult, if not impossible, to set up in practice in the living subject and unexposed nerve or muscle; it is, moreover, as has been said, a physiological rather than a pathological basis of treatment.

Under these circumstances, and based upon reasoning outlined in earlier pages of this contribution, the writer has adopted a plan of his own, based upon what he terms the polarity of metabolism. This plan practically applies a negative pole to all over-active processes of metabolism and a positive to all those processes which are under-active. Applying this to the treatment of the commoner diseases of the spinal cord, he would treat all the degenerations of nerve-cells or fibres of the cord with a positive pole, and all the inflammations with a negative pole, employing a long spinal electrode (one and a half inches by eighteen inches) according to the unipolar method. Thus, the negative pole, stabile over the cord, would be indicated in myelitis (acute, subacute, and chronic), in anterior poliomyelitis or atrophic spinal paralysis, and in insular sclerosis; while the positive pole, stabile, would be similarly indicated in progressive muscular atrophy, in amyotrophic lateral sclerosis, in locomotor ataxy, and in spastic paraplegia.

Contrary as it may seem, to usual electro-therapeutic practice with the continuous current, to use a negative pole to combat an inflammatory condition in nerve-tissue, the writer has satisfied himself, beyond all question, in typical cases of polyneuritis, that while the positive pole aggravated all the symptoms (pain, "numbness," prickling, paresis, muscular twitchings) the negative pole immediately assuaged these symptoms, and by daily use contributed to the comfort and the cure of the patients. Arguing deductively from these positive results in neuritis, as well as from the hypothesis as previously outlined, the writer would apply the same polarity—viz., the negative—to the inflammatory or active processes of cord diseases, ever keeping in mind, however, the difficulty of yet deciding exactly what the initial destructive pathological lesion is,—viz., whether, and at what stage, it is an inflammation or a degeneration.

It is, however, to be kept in mind that, though our pathological views be obscure, clinical results are often attainable from a variety of methods of placing the electrodes. In many instances it has seemed sufficient merely to include the diseased portion of the cord within the pathway of the greatest current-strength possible. This may be effected either by a transverse or longitudinal direction of current-flow,—transversely, by placing one electrode upon the sternum or any opposite part; longitudinally, by placing an electrode at the nape of the neck and the other at the lumbar region.

It is claimed that the spinal cord is stimulated or excited by applying cathodal galvanization up and down the skin over the .cord, while the anode is placed at the sternum, after the unipolar method, and that an opposite course produces sedation. According to Löwenfeld, the cathode at the upper end of the cord and the anode at the lower end produces anæmia, while a reverse arrangement produces hyperæmia. According to Uspensky, Onimus, and Le Gros, the cathode above and the anode below excite the cord and increase the reflex excitability, but the anode above and cathode below reduce the irritability of the cord and the excitability of the reflexes. According to Ranke, a constant current, irrespective of direction, passed longitudinally through the cord, diminishes the reflexes.

Brenner and Möbius refer to an increased power in the legs produced by longitudinal galvanization with the anode at the top of the cord and the cathode below.

Lewandowski acts upon the basis that the cathode is stimulating and the anode sedative, and applies one or the other to the seat of disease, according to these indications. If electrolytic effects are desired, he passes the current alternately up and down the cord by aid of the pole-changer, the electrodes fixed, or stabile. In general, to affect the upper extremities the cathode is placed upon the cervical enlargement, while to affect the lower it is placed upon the lumbar enlargement.

Erb advises mainly the galvanic current, stating that the most important point is that the current be allowed to act upon the diseased part with sufficient current-strength and duration. He is undecided as to the distinctive value of the poles, and is mildly inclined to give some importance to the direction of the current. Large electrodes are a prerequisite. As to special methods of application of the electrodes, he makes a distinction between the systemic or longitudinal diseases of the cord and the circumscribed diseases. In longitudinal diseases (tabes, lateral sclerosis, etc.) both electrodes are applied to the spine,—one at the neck and the other at the lumbar region. Both electrodes are then used alternately labile,—that is to say, one electrode is fixed, while the other is moved up and down the spine, and *vice versâ*,—or one electrode may be fixed upon the trunk anteriorly, while the other is moved up and down the spine.

In circumscribed diseases the entire site of the disease is covered with one pole, while the other is applied to the sternum or abdomen, both stabile; or both electrodes may be so placed, stabile, upon the spine as to convey the greatest possible current-strength through the diseased area.

Importance is attached to the indirect method of Remak,—viz., an effect upon the nutrition and the circulation of the cord produced by acting upon vasomotor and other afferent nerve-pathways. To this end the cervical sympathetic is treated, particularly when the cervical portion of the cord is affected. The cathode is placed over the upper cervical ganglion of one side (subaural galvanization of de Watteville), while the anode is moved up and down the spine upon the sides of the spinous processes opposite.

According to the metabolic polarity hypothesis of the writer, a long, stabile electrode is placed upon the spine, while a large, indifferent electrode is adjusted at the sternum. The spinal electrode measures one and a half inches by eighteen inches, and the sternal electrode nine inches by seven inches. A current-strength of from 50 to 75 milliampères is employed for from ten to twenty minutes. The polarity of the spinal electrode is determined by the nature of the disease. If this is believed to be of a degenerative type,—viz., an under-activity of the chemical exchanges which constitute its metabolism,—this electrode is made positive throughout the administration. If, on the other hand, the disease is believed to be of an inflammatory nature,—viz., an over-activity of the chemical exchanges,—the spinal electrode is made negative throughout the treatment.

Following our present rather obscure pathological indications, locomotor ataxy, primary spastic paraplegia, ataxic paraplegia, hereditary ataxy, senile paraplegia, progressive muscular atrophy, and allied diseases would be treated by the positive spinal electrode; while the varieties of myelitis, anterior poliomyelitis, acute ascending paralysis, and the diseases of the membranes of the cord, spinal meningitis (pachymeningitis and leptomeningitis), would be treated by the negative electrode.

Some authors prefer to combine the faradic and the galvanic currents, causing both to flow through the same pair of electrodes, and thus to act simultaneously upon the tissue. The currents are most easily combined by means of the de Watteville switch. This plan saves time, and is of undoubted value.

If desired, the internal rather than the external galvanic circuit may be applied to the treatment of cord diseases. This is effected by means of what is termed a body-battery, or galvanic couple. Such a couple is constructed by attaching a plate of zinc to a plate of silver by a flexible copper wire. Either the zinc or the silver plate, whichever polarity may be determined upon, may be cut to fit over the spine, while

the other plate, of large dimensions, rests upon the sternum or at some other indifferent point, both held in place by bandages. The zinc is now positive and the silver negative, since the fluids of the body are the electrolyte.

It is true the electro-motive force of such a couple is small, and for this reason it is claimed that the current excited cannot overcome the resistance of the skin. The objection would be valid were the skin to maintain its integrity; but any one may observe, after a very brief trial of such a couple, that the surface of the skin becomes covered with small pustules and minute, crater-like erosions beneath the zinc plate, due, doubtless, to both the electrolytic action and to the corrosive action of the oxychloride of zinc formed. For this reason the resistance of the skin is reduced to a minimum, and a steady current of small current-strength ($\frac{1}{50}$ to $\frac{1}{500}$ milliampère) flows. The advantage of such an application is that its action is continuous, day and night. I have, in many instances where it has been inconvenient to a patient to pursue a regular course of treatment, found that the galvanic couple, thus applied, has produced a decided effect upon the disease.

To affect the cord indirectly, or reflexly, as it is often termed, Rumpf places a faradic anode upon the sternum, while the cathode is applied to the skin of the back and of the lower extremities, until a decided rubefacient effect is established. This treatment he applied, with great success, to locomotor ataxy, attributing the favorable results to the circulatory and nutritional effects upon the cord due to stimulation of the sensory nerves of the skin.

In connection with the plan of influencing the cord by in-going impressions upon the sensory nerves excited electrically, Erb and others recommend that painful points should be separately treated. Furthermore, individual symptoms of cord disease, such as areas of hyperæsthesia and anæsthesia, the paræsthesiæ, pain, spasm and contractures, bladder, rectal and sexual troubles, paralysis, and atrophy, should be also separately treated.

There seems to be a general law, yet unformulated, that the centres and their peripheral extensions together constitute an integrality to such an extent that treatment to any part of the system constitutes treatment of the whole. This idea in electro-therapeutics is expressed in fragmentary forms, in the method of Rumpf, by the faradic brush; in the advice of Erb, to treat painful points; and in the so-called indirect catalysis of Remak, in which in-going impressions, *via* the sympathetic system, produce vasomotor effects.

It is, moreover, an axiom of hydrotherapy, experimentally established by Winternitz, that by means of thermal irritation the hyperæmia of an organ remote from the irritated spot can be augmented or diminished. Again, Hodge has demonstrated, by conclusive laboratory experiments upon cats, that the nerve-cells of the central ganglia are profoundly

affected structurally by continued irritation of their in-going peripheral nerves.

Experiment thus sustains the view that the gray matter of the cord and the circulation in the cord are modified by peripheral excitations or treatment. This law, as I believe it should be formulated, is that every internal organ has an area of skin innervation which represents it externally, and that by treating the external area electrically or in other familiar ways (sinapisms, heat, cold, pain, etc., etc.) we affect the internal organ. To represent these external or skin areas I have constructed two charts of the nude figure and shaded upon them the skin areas of referred pains. Familiar among such areas are the nape of the neck and alongside the spinous processes in neurasthenia; the region of the lower angle of the right scapula in disease of the liver; a similar area in relation to the left scapula in disease of the spleen; the distinct backache or pain across the lower portion of the lumbar region in disease of the uterus and in constipation; the spot over the ovary in ovaritis; the pain at the knee in hip-joint disease, at the temporal region in eye-troubles, at the epigastric region in stomachal disturbances; and so on through a long list not here essential to mention. In general electro-therapeutics I invariably attack these peripheral areas to produce internal relief, and with great and unexpectedly favorable results. This is comparatively easy by the administration of the franklinic spark. So far as relates to the special subject now under consideration, viz., diseases of the spinal cord, this course of treatment is, in my opinion, most worthy of practice. In spinal irritation the application is obviously pointed out by the painful areas along the vertebral spines, and it is not an unfair assumption that sparks, the faradic brush, or indeed any form of electrization to the terminals of the dorsal nerves in the skin over the spinal cord will take the usual in-going pathways to the cord and affect the progress of disease in it, by affecting its circulation, its nutrition, and those finer molecular pathological processes about whose nature we are now ignorant.

No less is the same argument true as applied to the constipation, the bladder, and the sexual troubles incident to many spinal diseases. These troubles should be treated by electrically irritative measures applied to the lumbar region, the perineum, and the region of the groins. Thus, as to the question of method we advise both a local, central, or direct treatment; and as supplementary to it, if not co-equal in importance, a treatment to every accessible in-going nerve-pathway to the central lesion.

For this reason I am more and more in favor, in the treatment of the diseases of the cord, of general applications which shall embrace within their scope not alone the local effects so long held to be desirable, but also the in-going impression effects I have just described, combined with those well-known nutritional effects upon the entire system now known to be inseparable from almost any general electrical administra-

tion. The methods, then, which best fulfill what should be done for the patient will comprise (*a*) local galvanization of the spine combined with the faradic brush by the Rumpf method; (*b*) the galvanic and faradic bath; (*c*) the franklinic bath combined with sparks to the entire person, but particularly directed to special skin areas capable of transmitting nerve-impulses to affected centres; (*d*) d'Arsonval's sinusoidal current; (*e*) the electro-static field caused by interrupted condenser currents, as first devised by the writer. Of these methods the first three may be put into practice by all; the last two are yet in their experimental stages, and do not, therefore, here require further consideration.

The writer's preference, in the treatment of these diseases by present available methods, is for franklinic electricity from powerful machines, with administration of long percussive sparks over the spinal cord itself, and a thorough "frictional" or peripheral spark treatment, accomplished by rubbing the patient's body over with a brass-ball electrode. In this manner is combined (*a*) central spark treatment to the cord; (*b*) general electrization of nearly all of the nerves and muscles; (*c*) peripheral excitation (by the spark, with electrode held close to the skin) of both motor- and sensory- nerve terminals.

An obvious difficulty in the way of an extended use of franklinization is the unwieldy nature of the apparatus. It cannot well be used at the bedside, and only exceptionally at the patient's home. For this reason, if for no other, we must sedulously cultivate careful methods of administration of the more convenient galvanism and faradism.

In practice, and in using franklinization, the writer regards no case of spinal-cord disease as fully treated until he has worked thoroughly over the skin-surface with the fine, burning, prickling spark from the influence machine. In the absence of an influence machine faradization of the skin with the fine-wire brush will doubtless answer much the same purpose. Clinical results, particularly in incipient cord disease, fully justify this method.

But as it is not here a question of individual preference, based upon an individual experience, the practitioner will, of course, avail himself of classical and established procedures, already, it is hoped, impartially outlined in foregoing pages. Certain it is that in electricity we possess an invaluable therapeutic resource in treatment of diseases of the cord. It is true that this opinion is sometimes shaken by a remark like that of Romberg, that locomotor ataxy and allied systemic diseases of the cord are incurable; by a contention like that of Möbius, that where electricity seemingly is beneficial the effect is in reality due to suggestion; by one of those waves of therapeutic nihilism that occasionally sweep over the medical profession; or, finally, by a mistaken point of view which puts into the mouths of the advocates of electricity the claim that scleroses may be replaced by normal nerve-tissue, and that hopelessly-incurable paraplegics may be caused to walk.

The field of usefulness of electricity in spinal-cord diseases is essentially in the incipient stages of the disease, or at least in a stage prior to extensive destruction of nerve-tissue, and in the amelioration of many of the untoward symptoms. The possibility of cure would seem to be in direct ratio to an early diagnosis; the possibility of a complete arrest of the progress of the disease at almost any other than the latest stages is established beyond cavil by the unanimous testimony of a host of competent observers; and, finally, it will doubtless be admitted, as a candid and impartial statement, that no other single therapeutic measure equals in any degree the scientific use of electricity in the diseases under consideration. If an individual case is finally decreed incurable or insusceptible of an arrest, there is at least the consolation that if a judicious use of electricity has not averted this direful termination nothing else would.

It now remains to devote some attention to the specific diseases of the cord. The methods of administration already outlined apply, with little variation, to the pathological processes which, though few in number, are undoubtedly similar, and yet, anatomically, are diversely located, thus giving rise to a considerable number of descriptive names. For this reason much that is said of one disease will apply to another.

The writer must content himself with a brief exposition of the salient features relating to the treatment of individual diseases. His first plan was to give a short abstract of the opinions and practice of competent observers during a recent period of years, as expressed in standard works upon the subject and in current literature; but, after collecting these references, he has found that their volume is far beyond the scope of the space allotted to him in this section, and is, moreover, satisfied that a mere encyclopædic compilation, interesting as it undoubtedly is, and just as it would be, to eminent authors, must yet fail to leave fixed ideas of treatment, since, in a multiplicity of views, few concrete ideas are retained.

DEGENERATIONS OF THE CORD.

Locomotor Ataxy (*Posterior Spinal Sclerosis; Tabes Dorsalis*).—Beginning with degenerative diseases of the cord, locomotor ataxy may be conveniently taken up first, since its treatment, owing to the comparatively large number of its symptoms, will bring into prominence a greater variety of electro-therapeutic procedures than the remaining affections of the same class.

Its symptomatology and diagnosis are familiar to all. Its chief characteristics are pains, ataxia or inco-ordination, anæsthesia, visceral and trophic troubles. The seat of the lesion is in the posterior columns, the posterior nerve-roots, and frequently in the peripheral nerves.

There can be no doubt as to the beneficial effect of electricity in this affection. Not only can we rely upon the concensus of opinion of many

authors, but almost every one who has had experience can recall cases where the important symptoms have been caused to disappear, and the patient to resume a life of comfort and comparative activity. This remark applies mainly to the initial and the ataxic stages.

Galvanization has long held a foremost place in producing these results. Time, patience, and careful work will be required. A chronic disease will most likely demand chronic treatment. The electrodes should be large. The current at first of moderate current-strength,—say, 2 milliampères to a square inch; and the duration brief,—say, ten minutes daily. Soon the current-strength may be carried up to the point of toleration, and the sittings prolonged to twenty minutes. The method employed by the vast majority of the best authors is as follows: Stabile galvanization of the cord, together with both stabile and labile applications to the nerves of the extremities. Upon the cord the stabile electrodes are placed, one at the nape of the neck and the other in the lumbar region. Or one electrode may be fixed in an indifferent position, as upon the sternum, while the other is fixed upon the spine.

It is, however, apparently equally good practice to use both electrodes alternately, stabile and labile; that is to say, one electrode is fixed, while the other is moved up and down the spine, and *vice versâ*.

Frequently, subaural galvanization is practiced with a view of influencing the sympathetic nerve; in this case the cathode is placed in the subaural space (over the upper cervical sympathetic ganglion), while the anode may be used labile upon the spine. Painful points receive stabile anodal treatment. Other symptoms relating to the muscles of the eyeballs and to the optic nerves, anæsthesia and hyperæsthesia, sexual, bladder and rectal troubles may be individually treated with the hope of beneficially influencing the respective spinal centres or of producing local improvement.

It is of special importance not to neglect the treatment of the nerve-roots and the peripheral nerves, since they, as well as the posterior columns, are, in many instances, the seat of pathological changes, —if, indeed, they are not often the original starting-point of the disease.

To use galvanism by means of the bath, the reader is referred to the section upon "Lateral Sclerosis." The use of a galvanic couple has already been described.

As regards faradization, its greatest success has been by the Rumpf method, referred to. Lewandowski reports that, according to this method, combined, it is true, with stabile, labile, and subaural galvanization, he has treated one hundred and twenty cases of tabes, with twelve cures, *i.e.*, 10 per cent; the knee-jerk returned and all the symptoms of the disease disappeared, while in cases considered incurable in 80 per cent. the gait improved, the ataxia and pain was diminished, and the pupil symptoms caused to disappear. The improvement lasted for months and years, while the cures were permanent.

Rumpf himself has reported most favorable results by his method of the farado-cutaneous brush. The procedure would seem to be best adapted to cases where pain and paræsthesiæ are predominant symptoms.

There is, on the whole, a fairly unanimous opinion among authors as to the value of galvanization and faradization, and as to the methods to be pursued.

It remains to refer to franklinization, and what is here said in regard to it applies equally to the other spinal-cord diseases. The writer has records of a large number of cases treated solely by this method, both in private practice and in his clinic. In hospital practice and in teaching students, where it has been his aim to present all methods of electrization impartially, and where for purposes of control no medicines are used, a given case of locomotor ataxy has often been placed under galvanic or faradic treatment by approved methods, conscientiously carried out. But it has been a common experience that, failing to make the progress desired, the patient has been put under treatment by franklinization. From this moment improvement would become manifest not alone to the physician, but to the patient, who, once treated in this manner, would protest against going back to the old methods, although the new was for the time being more painful to him, and from every point of view less agreeable to receive.

In thus speaking emphatically and in praise of franklinization, the writer does not refer to the paltry administrations of small and toy influence machines. He has yet to see a machine too large for practical work. The smallest size of machine which, in his opinion, can be of real use should possess at least six revolving plates, each of which plates should measure at least twenty-six inches in diameter. The Wimshurst-Holtz type of machine furnishes the best working spark, and a dense electro-static field for use as spray and as an electro-static bath.

With such a machine thick percussive sparks from four to eight inches in length can be administered over the spine, to nerve-roots and nerve-trunks, to the muscles, to paræsthetic areas, and to all points from which in-going impressions may be caused to impinge upon the spinal gray matter or to affect the spinal circulatory mechanism. The density of the charge from such a machine is likewise sufficient to afford a powerful rubefacient or fine spark to excite to cutaneous peripheral nerve-distribution. By such means a vigorous and very complete treatment can be carried out in about fifteen minutes. The temperature before treatment should always be taken. Often it is subnormal by about a degree, and it will be raised to normal. If above normal, it will be reduced to about normal.

I have supposed that the action must be a regulating one, due to an effect upon the thermogenic centre. In a large number of cases where the quantity of urea has been determined before treatment it has been found to increase after each sitting, and during a course

of treatment to maintain an average increase over and above the amount prior to treatment. The pulse likewise exhibits characteristic and invariable modifications: if normal or below normal, it is increased in frequency; if much above normal, its frequency is lowered.

Could experiments be carried out to determine increased respiratory capacity, I doubt not that it would be demonstrated that franklinization increases the consumption of oxygen by promotion of the metabolic exchanges, just as d'Arsonval has proven it to be the case in the administration of the sinusoidal current. In the effects alluded to we have summed up a picture of profound nutritional excitation, of which the structural lesion to be attacked has undoubtedly, in due ratio to the rest of the economy, received its due quota. And to this, what may be termed a constitutional or nutritional effect, we have added a local effect upon the diseased part, for each long and percussive spark to the immediate neighborhood of the lesion has created an impression upon it. What this impression may be is not wholly a matter of conjecture. It is, with certainty, a concentrated electric current of enormous electromotive force (at least 1,000,000 volts) localized to the tissue immediately in relation with the disruptive discharge or spark. Electricity of this sort moves, displaces, distorts, and strains matter like living tissue, as well as dissipates itself in current form through it. In this sense the action may be said to be mechanical and the tissue to suffer, as has been pointed out in reference to dielectric tissue, a condition of electric stress; and, from this point of view, the disturbing action of the spark upon tissue may be conceived of as resembling a sort of molecular gymnastics. In other words, mechanical, as well as electric, excitation is a peculiarity of the spark, and must justly be taken into account to explain the profound effects clinically observable from a proper use of franklinization.

A case of locomotor ataxy cannot be said, in the opinion of the writer, to have had the full benefit of what electricity can accomplish until it has been treated by the franklinic current.

By this means I have seen the swaying symptom, the ataxia, the pain, the anæsthetic areas, the bladder and sexual troubles completely disappear, the field of vision to greatly enlarge, and the gait to become normal. I have never known the knee-jerk to return, nor have I ever seen what I should regard as a complete cure. But I have seen complete arrest of the disease, lasting for years,—and this, too, in the second or ataxic stage; and I know of patients who, relieved from their distressing pains and crises and restored to a fairly-natural gait, are most thankful for at least this much.

Primary Lateral Sclerosis; Primary Spastic Paraplegia.—The symptom-complex of sclerosis of the lateral columns of the spinal cord is much simpler than that of the posterior columns, just treated of. The spastic gait, the exaggerated reflexes, and the absence of sensory, sexual, rectal, and bladder symptoms form a clearly-defined symptomatic picture.

The electrical treatment is mainly directed to the cord and to the affected muscles. It is conducted upon the same general plan as outlined for sclerosis of the posterior columns. Both galvanization and franklinization produce a decided impression upon the disease; they improve the patient's general health, reduce the tendency to clonic spasms, and reduce the severity of the tonic or spastic rigidity, thus improving the gait. In early stages I am positive that, in some cases, the patient is cured or the progress of the condition arrested. This may well be expected in a disease which owes its identification not to distinct pathological findings, but to the convenience of symptomatological grouping. For spastic paraplegia may be due to chronic dorsal myelitis in adults, and in children to brain lesions followed by hemiplegia; it may be due to the syphilitic virus; or, finally, it may be of a functional and evanescent type. In the later cases, if we could but recognize them in advance, the patient might, of course, have recovered without any treatment.

Reference to the use of the electric bath in cord diseases has been deferred until this point, in order to introduce this method in connection with the disease now under consideration. The details following are generally applicable to most diseases of the cord.

According to W. E. Steavenson, in the London *Lancet*, i, 709, 871, 924, the electric bath is a valuable agent in the treatment of lateral sclerosis. He reports that great benefit has been obtained by the general galvanic bath. The positive pole is always placed at the head, so that the current enters the spinal cord between the shoulders. The current seems to have some specific action on the cord, and tends to reduce reflex excitability. Under this treatment the spastic gait is improved and the tendency to tonic spasm decreased.

Every precaution must be used to prevent the possibility of the patient receiving any shock. A course of baths may consist of thirteen or fourteen baths, one every day for five or six days, and then every other day till the end of the course. More are admissible, but this is usually sufficient for marked improvement that remains until some fresh cause arises that induces a relapse. Each bath continues ten or fifteen minutes. Afterward the patient should feel refreshed and exhilarated, should rest for fifteen or twenty minutes before going into the air, and refrain from engaging in any exhausting exercise. A feeling of languor and depression following each bath is an indication that this particular form of treatment must be discontinued.

The bath itself, which holds the water, may be of metal, porcelain, or wood. Japanned metal is unsuitable for any form of electric bath. The very best material is oak, carefully painted inside with non-metallic paint. Metal plates at the head and foot of the bath are the electrodes. Each is provided with a binding-screw, to which rheophores from batteries can be attached. The electrode at the head is the larger, measuring a foot and a half by one foot, while the lower one measures eleven inches

by nine. Small plates for the hips and knees may also be used, whenever it is desirable to localize the current more or less to these parts. The water should always be deep enough to cover the plates, the patient being immersed up to the chin. The shoulders and back are prevented from touching the plates at the head by a rest made of wood, something like a picture-frame, across which are stretched pieces of webbing. A depression made in the upper bar supports the back of the patient's head. The feet may be placed on the lower electrode, or kept near it. The galvanic current will always prefer to traverse the human body when placed in ordinary water, as the body is the better conductor; but not so greatly superior as to insure all the current passing through it. The water in the bath offers a broad conducting medium with a large, transverse sectional area, several times larger than the patient. Only a fifth part of the current traverses the human body. Thus, with a current-strength of 200 milliampères passing through the bath, the patient gets 40 milliampères only. A good cell is a large, No. 1 Leclanché. A Stöhrer battery may also be used, and cells added to the circuit by the traveling commutator, two cells being added at a time.

On entering the bath, which is heated to 98° or 100° F., the patient is allowed a few minutes to recover from the reaction of the warm water before the current is turned on. The current should be increased slowly and reduced gradually at the end of the bath, the galvanometer being carefully watched while these changes are being made. The physician should always be present to regulate the current and watch the effect of the electric bath. Fullness about the head may be relieved by a cold, wet towel; and a feeling of faintness by reducing the current. Pulse-rate and respiration are said to be decreased during an electric bath. Early experience led to the belief that cases of spastic rigidity, accompanied by severe tremblings and sudden contractions of the limbs in bed, were more amenable to treatment when the result of injury to the brain or cord was by direct violence; but latterly similar abnormalities, due to lateral sclerosis and descending irritative lesions of the lateral columns, have also been found to improve greatly by treatment with electric baths.

It is superfluous here to more than mention by name Friedreich's and hereditary ataxy, since only about two hundred cases are upon record of the former, and the latter is infrequent. The disease develops in early youth; and since etiologically it is thought to be due to an imperfect development of the spinal cord, electricity will naturally take its due place with other hygienic measures.

Ataxic Paraplegia.—This is a combined disease of the lateral and the posterior columns; its symptoms are those both of primary spastic paraplegia and of ataxy. Here, again, as in spastic paraplegia, the nomenclature and diagnosis are based upon a sufficiently clear symptomatic picture, rather than upon a pathological basis. Most of the cases are

thought to be due to chronic dorsal myelitis with secondary degenerations, or to be practically cases of locomotor ataxy with an attending degeneration of the lateral columns. It is difficult to decide in most cases, particularly the subacute, whether the disease has or has not a focal onset followed by degenerations of the two columns. If a level of focal myelitis can be diagnosticated, and early diagnosticated, electrical treatment should be at once initiated over the circumscribed area, and according to the principles applicable in subacute inflammatory conditions. Apparently it cannot be conceived of, in a truly scientific sense, that the same electrical treatment is indicated in an inflammation as in a degeneration; but in this disease, as in many others of the spinal cord, both conditions are probably present. And since the former, in this instance at least, may be prior to the latter, treatment should be at first, as has been said, directed to it if the sequence of events can be established.

Negative galvanization, cathode to the focal level of the cord and anode to the sternum, should be carefully tried. Strong franklinic sparks to the same area are indicated, the patient seated upon a positively charged and insulated platform. If the disease is to be treated from the point of view of a degeneration, the indications for treatment applicable to locomotor ataxy and lateral sclerosis are called for.

Progressive Muscular Atrophy; Wasting Palsy; Amyotrophic Lateral Sclerosis; Chronic Poliomyelitis; Progressive Bulbar Palsy.—In the degenerative diseases thus far referred to the degenerative process has had its main seat in the white columns of the cord; in the above disease the process has its chief location in the gray columns comprising the anterior horns. It is, however, not confined to these columns; it may also invade the pyramidal tracts, the motor roots, and the motor nerves. But, as Gowers has pointed out, the disease most frequently involves the entire lower segment of the motor path. The motor pathway extends from the cortex of the brain to the muscles. This lower or spino-muscular segment comprises the spinal motor cell in the anterior cornu and its fibre or nerve extension through the anterior root and nerve-trunk to the muscle.

When the anterior horns and the pyramidal tracts are the first to be attacked, the disease is commonly referred to as a progressive muscular atrophy, while if the nerves and muscles are primarily attacked it is termed a progressive muscular dystrophy. From no point of view is it now tenable that the disease, as once supposed, is a primary disease in muscles or of the sympathetic nerves.

It is essentially important, in the treatment of this disease by electricity, to have a clear perception of the location of the lesion and of the differences of symptomatology above pointed out. When the degeneration invaded the pyramidal tracts the disease was termed "amyotrophic lateral sclerosis," by Charcot, upon the assumption that these columns were its primary seat. Gowers objects to setting up this

variety in the mode of onset as a distinct type of the disease, and considers that, on the whole, there is a tendency to degeneration in every part of the motor tract, from the cortex to the muscle, and that at one time the spinal ganglionic cells and their prolongations to the muscle (lower segment) may take the chief brunt of the attack, while at another the pyramidal tracts and the higher ganglionic cells, even at the level of the cortex, may first succumb, thus giving rise to the familiar variations in the symptomatology of the disease which are so frequently presented.

It must be borne in mind, in relation to treatment by electricity, that progressive bulbar paralysis due to atrophy of the nuclei of the nerves supplying the muscles of the lips, tongue, palate, and throat, and exhibiting the characteristic paralysis and wasting of these parts, falls within the scope of progressive muscular atrophy. In estimating, however, the value of any treatment, electrical or otherwise, the results attained must be justly weighed in the balance against the uncertainties of diagnosis. This is particularly the case in bulbar paralysis, which, though presenting a characteristic symptom-complex, has more than once been found, upon post-mortem examination, to reveal no microscopic or other lesion of the medulla.

A differentiation between a true and a pseudobulbar paralysis is not always easily made. In case of doubt, the electrical reactions possess a decisive value. In the pseudobulbar paralyses the electric reactions are normal,—*i.e.*, neither diminution of faradic excitability nor qualitative or quantitative galvanic reactions are present.

It need scarcely be mentioned that in progressive muscular atrophy, as in all spinal-cord diseases, the course of the disease is to be carefully watched by recording the "reactions of degeneration," according to the principles so brilliantly outlined by Erb. But as separate consideration is given to that subject in other parts of this work, it is superfluous to allude to it, especially as proper details would require much space. In progressive muscular atrophy the degenerative reaction is very early established, that is to say, in the form that C. C. C. quickly loses its excessive relation to A. C. C., and soon the two are equal, then proceeding to the point where A. C. C. $>$ C. C. C. Accompanying the changes in galvanic irritability, the faradic is diminished in a relative degree. The diplegic contraction of Remak may be sometimes obtained. The galvanic negative electrode is placed over the fifth cervical spine, the positive on the neck, and the current interrupted. Again, according to Voeter, a palmar spasm may be noticed when using the faradic current or the interrupted galvanic upon the arm.

The course of the disease varies greatly both as to its duration and its type (as has been referred to). It may advance to a certain stage, and then cease for a period of time, only to reprogress; or the cessation may, exceptionally, be permanent. The greater number of cases would

seem to be incurable. In forming an opinion as to the curative value of electricity in this affection, we must be influenced by the foregoing facts. I have seen both a fatal and a favorable termination of cases treated in exactly the same manner. The fatal cases were of the upper-arm type, progressing rapidly (about two years to time of death), and extending to bulbar disease and paralysis of the respiratory muscles. The favorable cases were of the lower-arm type, with wasting of the thenar, interossei, and extensors and flexors of the forearm. In one of the latter instances the speech was also affected, and yet now for two years the patient remains perfectly recovered, except as to the remaining defects due to the muscles lost to use.

Many recoveries may doubtless be explained by errors of diagnosis. The disease is apt to be confounded with chronic poliomyelitis anterior, syringomyelia, and neuritis. In polyneuritis I have seen wasting of the shoulder-group of muscles, which, were it not for accompanying symptoms, like pain, etc., scattered throughout the body, might well be regarded as due to progressive muscular atrophy.

Electricity is pre-eminently indicated in this disease not alone to the affected centres, but also locally to the affected muscles. Local faradization and galvanization, the entire length of the spine, is recommended by many authors. Duchenne advises faradization of all the affected muscles, combining with this, however, a further application of a positive pole of the continuous current upon the vertebral column and the negative over the affected muscles.

Erb prefers galvanization alone, stabile, with both poles and mild currents to the affected levels of the cord. (See table, page 79.) In addition, mild galvanization or faradization of the neuro-muscular tracts affected (cathode, labile; anode, over the site of the disease) may be resorted to. He regards the prognosis as decidedly unfavorable. Gowers says that the most sedulous and skillful use of electricity, voltaic or faradic, fails, as a rule, to produce alone any effect on the course of the disease; and that, if the disease is progressing at an equal rate in both arms, and *the muscles* (italics ours) of one arm be treated and the other not, the muscles of the treated arm will show no improvement in the rate of wasting over the other. It is possible, however, he adds, that electricity sometimes does a little good. The arm comparison would hardly seem to be a just one, since the disease is not believed to be local to the muscles. His advice that galvanization should be employed in moderation, and watchfully of its effects, is borne out by my experience, since the condition of the patient may easily be rendered worse by too powerful applications of the continuous current to the cord. There is a danger, however, of drifting into habits of too great caution, and of thus rendering one's efforts futile. With a spinal electrode one and a half inches by eighteen inches, and a sternal seven inches by nine inches, I have found 25 milliampères not an excessive current-strength. I prefer

to place the positive pole at the vertebral column. After ten minutes' current-flow the spinal electrode may be replaced, the sternal still *in situ*, by another electrode, which can be used gently labile over the affected muscles with positive electricity, as at the spine. For it would seem proper to treat the entire affected tract by the *same* polarity. The plan above described accomplishes this purpose.

My personal experience leads me to prefer the franklinic current in this disease,—long percussive sparks to the vertebral column; smaller sparks, such as are easily borne, to the muscles; frictional or rubbing electrode to the entire skin surface; and positive insulation or bath during twenty minutes. According to a plan discovered by the writer, a special current may be obtained from influence machines by connecting rheophores and wet-sponge electrodes to the outer coatings of the Leyden jars and allowing a short spark to pass between the discharging rods. This current has already been described as the static induced current. It is, in reality, a current differing from any current in use in medicine, owing to the combination of the high frequency of its alternations or oscillations (millions per second) and its high electro-motive force (several hundred thousand volts). It is essentially a high frequency, high potential current. No chemical decomposition attends its flow, but, in lieu of this, great molecular disturbance takes place. The resistance of the human body may be said to be almost *nil*, and all parts are easily and equally penetrated by it. This static induced or condenser current is especially adapted to reaching and influencing the spinal marrow.

In connection with the disease now under consideration, I will mention most briefly a case treated by the static induced current, with arrest of the disease:—

T. J. V., aged 53; November, 1891. Neurotic family history. Eight years ago had diplopia and ptosis, which latter still persists. No further trouble until eighteen months prior to present date, when he noticed that he could not extend the left index finger, and soon the right middle finger was in the same condition; the left thumb next lost the power of apposition to the index finger, and he lost the control of the hands and fingers. The thenar muscles and the interossei then began to atrophy and hollows to form. A characteristic griffin-claw appearance of the hands was established. By the time of the date of his visit, as above, both wrists were dropped, owing to atrophy of the extensor muscles of the forearm. There were fibrillary twitchings of many of the small muscles of the hand and of the forearm muscles. Constipation habitual. Legs heavy and weary. Speech slow and deliberate, as if early bulbar trouble was present. Reaction of degeneration (loss of faradic excitability and C. C. C. equals A. C. C.) in forearm, and hand-muscles affected. Mechanical excitability of muscles well defined.

Treatment.—Static induced franklinic current, two connected metallic foot-plates, positive pole to feet; one large sponge electrode—negative pole—over cervical enlargement; gallon Leyden jars; one-half-inch spark between discharging rods. Duration twenty minutes.

This treatment was carried out three times a week, from November 23 to December 26, 1891. Patient then reported that he felt much better—felt refreshed and strong; could walk five miles; wrist-drop so much improved that both hands could be raised level with the arm, though the effort caused contortion of some of the fingers. Fingers cannot be extended, but he can now hold his cup of coffee in either hand.

February 11, 1892. Though constipated for years, two weeks ago his bowels began to move every other day, and this week every day. Gained seven pounds in weight; a good color has returned to the face.

February 20th. Temperature raised $\frac{8}{10}$ degree Fahrenheit after treatment.

March 16th. Temperature before treatment, 97 degrees; after treatment, 98.2 degrees,—an elevation of $1\frac{2}{10}$ degrees.

April 29, 1892. Patient's general appearance entirely changed; face ruddy and full; has been gaining flesh steadily every month, but during the last two months has increased in weight from 157 to 162 pounds. Extension at the wrists is recovered, and the forearm muscles exhibit no fibrillary twitchings nor mechanical excitability; their electrical reactions are normal. A very slight and superficial sulcus marks the position of the affected group. The hollows due to atrophy of the interossei and thenar muscles remain, together with the same distortion due to these losses; but, upon the whole, the hands are much improved. There is a complete arrest of the progress of the disease to date of this writing, September, 1893.

Other cases of progressive muscular atrophy, as well as the various diseases of the cord, have been treated in this manner, at my clinic at the New York Post-Graduate Medical School, with excellent results. I do not suppose that a choice of poles is of importance, since it is not here a question of electrolytic action.

Finally, we may say that the preponderance of evidence is in favor of the dictum that no case of this disease should fail to receive proper electrical treatment. And recent advances in electro-therapeutics may well lead us to expect much greater benefits than have hitherto been derived. When the alternating sinusoidal current with its profound nutritional effects, as pointed out by d'Arsonval, when the high frequency, high potential currents first introduced in 1881 into practice by the writer, have been thoroughly tested, and when the generally improved methods now creeping into practice have a wider vogue, the ratio of success in arresting or curing this as well as the other cord diseases will undoubtedly increase.

INFLAMMATORY AND OTHER DISEASES OF THE CORD.

The sense in which the inflammatory conditions incident to the spinal cord and its membranes is to be accepted has been referred to in other pages of this contribution. In general, as indicative of the uses to which electricity may be put to combat the conditions of this class, it is sufficient to here point out that the inflammatory processes, here as elsewhere, are characterized in general by connective tissue and vascular activity, and in particular by cell destruction and nerve disintegration, preceded, respectively, by changes in the cells and swelling of the myelin sheath of the nerve and of its axis-cylinder. The process would seem to be essentially an active one, rather than, as in the case of the degenerations, a simple decay or wasting of the parts involved.

Anæmia and Hyperæmia.—Circulatory changes which affect the function of the cord without causing organic changes in it, or which, on the other hand, may be preliminary, in a restricted sense, to structural

changes, may possibly exist; but such changes are as yet undemonstrated and, in reality, unessential to a rational explanation of the present recognized diseases.

Attention has recently been called to a possible condition of arteriosclerosis in the vessels of the cord as explanatory of the stages which lead up to a developed locomotor ataxia. As a result of the consequent diminished blood-supply, atrophy and degeneration of the nerve-elements ensue, and a final sclerosis of nerve-tissue follows. Gowers, referring to the thickening of the walls of the vessels seen in some cases, considers that its pathological bearings are unimportant, and that the disease undoubtedly takes its origin in the nerve-elements themselves. The contention, in regard to this general question, is not that variations in the circulatory flow of the blood in the vessels of the cord do not occur under circumstances of increased physiological activity, etc., etc., but that there is no permanent subacute or chronic excess or deficiency of blood-supply of sufficient note and sufficiently local to the cord alone to justify the diagnosis of either anæmia or hyperæmia. Could we be certain of such a diagnosis, these conditions could be electrically combated with some degree of precision; for the vasomotor effects wrought by the electric current are most positive,—at least, in superficial regions of the skin and in membranes and organs where this effect may be studied, and, by parity of reasoning, in deeper organs. The reddening of the skin by either pole of the galvanic current and the capillary stasis in the web of a frog's foot or in the mesentery are instances in point, as well as the more extended effects in human beings attending galvanization of the sympathetic nerve in the neck. Both poles of the continuous current produce a local hyperæmia. But there is no satisfactory evidence that these effects can be produced in the cord itself; while, at the same time, there is no reason that they should not be. Their production has a most important bearing in the treatment of symptoms due to vasomotor spasms in the cord; for, in this event, the effect of electricity is to restore the arterial tone. In this connection we will repeat the advice of Löwenfeld: to apply the cathode to the neck and the anode at the lumbar region, both stabile, to cause anæmia of the cord, and to reverse these positions to cause hyperæmia. In this manner he treated the two conditions, viz., by the reverse effect of the current. Hyperæmia of the cord was treated by Rumpf by means of the farado-cutaneous method described.

The writer has had but little experience in the treatment of the two conditions under consideration, since he has seldom been able to regard them as morbid entities. But anæmia of the cord deserves some recognition as a pathological factor in spinal irritation; itself, however, only a small part of a more general condition of neurasthenia.

Inflammation of the Cord (*Myelitis*).—The inflammation of the spinal cord known as myelitis may be an acute, a subacute, or a chronic

process. Its most common type is an acute, transverse myelitis, in which the affected part of the cord often undergoes "softening," and the circumscribing meninges are adherent and thickened. In this acute form the patient is found, within a few hours, to be a paraplegic with motor and sensory paralysis, girdle sensation, and incontinence and retention of urine; or, if the cervical enlargement be attacked, with paralysis of the arms. Further acute symptoms need not be here described. In a few weeks, should the patient survive, improvement sets in, first noticed by a return of sensation and a gradual recovery of some power of motion. But now develop, if the attack has occurred in the lumbar region of the cord, contractures and spasms and excessive reflex action. The patient, if sufficiently recovered to walk, presents the appearance of spastic paraplegia, or the motor paralysis and contractures may be of such severity as to cause deformity of the legs and confine him to his bed.

The disease has now progressed to a stage where it is generally regarded as a "chronic myelitis," and such cases constitute a class which the physician is most commonly called upon to treat by electricity. But the electrical treatment should be begun early; at least, after the end of the third week, if no fever be present. In order to ascertain early if degenerative changes have been set up in the nerve-fibres, the faradic current (Gowers) should be applied to motor points of the muscles on the seventh to the tenth day. If, by this time, the muscles still preserve their normal irritability, it is positive that no important change is taking place in the nerves, and that, consequently, no serious destructive changes are taking place in the gray nervous substance from which these nerves proceed. Such an examination of the muscles further serves to localize the level of the cord affected and to determine its focal or non-focal character. It is, therefore, an important diagnostic, as well as prognostic, procedure, and adds greatly to precision of observation and treatment.

In using galvanism the electrodes are placed stabile, one above and one below the circumscribed area of the lesion, or one directly over it and the other upon the sternum. In either of these positions the current is to be frequently alternated by means of the pole-changer, the alternations to succeed each other at intervals of about one-half a minute. If, however, secondary descending generations of the lateral columns have evidenced themselves by exaggeration of the reflexes and spastic rigidity, the galvanic treatment should be administered in the length of the cord with stabile electrodes, the positive pole at the nape of the neck and the negative at the lumbar region, and, after a few minutes, a reversal of the direction of the current. Frequent alternations are not now called for. Anodal galvanization is often advised for a sensitive area over the vertebral column, if one can be discovered.

Rumpf's farado-cutaneous method of cathodic faradism to the skin of the back and the lower extremities is also advised by himself and E.

Remak. The current-strength must be determined by the size of the electrodes employed, by the sensibilities of the patient, and by the effect upon the symptoms. Mild currents should be first employed, and the strength soon be brought up to the point of tolerance. Many observers report untoward effects from too great current-strength.

In addition to the central treatment, the peripheral symptoms relating to the bladder, the nerves, and the muscles will be treated by the usual methods. As regards franklinization, the sparks will be delivered over the affected area of the cord and to the periphery; owing to the inconvenience due to the size of influence machines, cases of myelitis naturally do not come under this treatment until in their later stages. The chief hope with the spark treatment, as with the slowly-alternating (one-half minute) galvanization, is to effect an absorption of the exudates and to hasten the regeneration of nerve-fibres. Electricity, in all its forms, hastens the return of sensation. Brilliant results are often claimed in the treatment of this affection; and, indeed, if electricity be early applied, its effects are most satisfactory. But after the secondary degenerations have become established, together with the clonic or tonic spasms or contractures and the spastic gait, it is well to advise the patient frankly that these symptoms are incurable, and admit only of a greater or less degree of amelioration. The lesson taught by this unfortunate situation is to begin the electrical treatment early. Having no experience of the treatment of this disease in its early stages (first and second weeks) by electricity, as, probably, no one else has, I should yet like to treat the disease at that stage. Its level (if focal) once established, as could easily be accomplished by an electrical examination of the muscles, I should apply a negative pole of the continuous current, stabile, of the largest current-strength which would be tolerated by the patient, over the affected area for from ten to twenty minutes daily, using large electrodes; the positive pole would be placed upon the sternum. This I would advise, after an extended and satisfactory experience with the same polarity in every form of neuritis, in its most acute stages. I have always found immediate relief and permanent benefit to follow this treatment of nerve-trunks in the acute stage of inflammation, and I see no reason to doubt that a similar stage in inflammation of the nerve-elements of the cord would be followed by similar results.

Surely it is that electricity is called upon too late in the treatment of nervous diseases. When nerve-cells and nerve-fibres have been destroyed or nerve-fibres almost hopelessly impaired in their structure, when connective-tissue proliferation has had its full time and the scleroses are established or meningeal exudates are formed, then, and only then, and when it is too late to procure the best results, electricity is called upon for aid. This view of the province of electricity in the cure of disease is derogatory to the real power of the agency. Not "till the

war is carried into Africa," not till *acute* diseases are subjected to its influence by careful experimentation, shall we know of the real value of electricity in medicine. If it has no merit beyond the amelioration of the general conditions of incurable diseases, its use may well be transferred to the hospital nurse; but if it is a potent therapeutic agency, multiform in effects, controlling in its influence upon both acute and chronic morbid conditions, as the writer believes it to be, then its use should be extended, and in no case would such an extension be more pertinent than in an attempt to allay the severity of the onset of the acute inflammatory process incident to an acute myelitis.

Chronic Myelitis.—That form of chronic myelitis sequent to an acute attack, and characterized, as a rule, pathologically by an area of chronic reparative (Dana) and necrotic processes affecting a given level of the cord, has just been sufficiently referred to. It is the most common form of the disease. Chronic myelitis also includes those cases in which the inflammatory process is from the onset gradual, and not necessarily associated with an acute attack. This form is less common. Nothing further remains to be said of its treatment, except that it should be pursued with patience, and with not too excessive expectations of cure. The chief hope lies in causing an absorption of the exudates at the affected level, and thus relieving the nerve-elements of pressure. From this point of view alone, the negative pole—stabile—of the continuous current is indicated, by reason of its known influence upon exudative material. And since these patients are anæmic and exhibit every sign of impaired health, they should, if possible, be treated by franklinization for this, if for no other, reason. From this same point of view the general faradization or central galvanization of Beard and Rockwell, or galvanic or faradic baths, or any other form of general electrization, may be resorted to.

Compression Myelitis.—The diagnosis must be made according to well-known neurological data based upon the special character of the disturbed physiological function of the cord, chief among which is pain due to pressure upon the nerve-roots. There may also exist a local tenderness of the spine. Pressure may be due, among other causes, to a tumor of the cord itself, to a tumor of the membranes of the cord, to caries of the bone, and to thickening of the membranes (pachymeningitis).

Treatment must be directed both to the supposed cause of pressure and to the resulting myelitis. It is in such a case that the aid of a specific polar action may be invoked. The negative pole—stabile—of the continuous current is believed to possess the most value in the absorption of exudates. This may be due to the principle of cataphoresis, according to which an increased amount of fluids is directed to the cathodic end of a semi-fluid electrolyte. Franklinic sparks may also be cautiously applied.

Acute Anterior Poliomyelitis; Acute Atrophic Paralysis; Infantile Spinal Paralysis; Essential Paralysis of Children.—Acute anterior poliomyelitis is essentially a disease of children, occurring, in the majority of cases, before the third year, and infrequently after the tenth. It is characterized by a sudden motor paralysis, followed by wasting of some of the affected muscles. By contraction of unopposed muscles deformities ensue, mainly talipes equinus, varus, and valgus. Sensory symptoms are absent.

From the point of view of the therapeutic use of electricity we may most conveniently divide the course of the disease into the following four stages:—

1. The acute invasion stage,—several days.
2. Stationary stage,—several days to six weeks.
3. Stage of retrogression,—six to twelve months.
4. Chronic stage, with "remaining defects."

Further description of the symptoms of the disease, its diagnosis, and its pathology must be sought for in the usual text-books.

Uniform experience of the best authors inculcates the extensive use of electricity in this affection. Treatment is called for with certainty in the three last stages above named, and the hope may be justly indulged in that data will yet be forthcoming to also justify active interference, by aid of electric currents, in the very earliest recognizable onset of the malady, with the expectation of at once curtailing the severity of the focal inflammatory process in the anterior cornua, and of thus limiting to a minimum the disastrous remaining defects.

If electricity can, upon trial, be found to mitigate the severity of the initial exudative inflammation in the gray matter, or, better still, to cause its resolution, then to delay its use until the conventional periods now established by custom have arrived would be folly. Experiments should be conducted upon an extended scale to determine whether treatment in this early stage may not be of advantage. Illustrative of the pressing necessity for limiting the inflammation of the gray matter to the least possible minimum, we may quote from Gowers the remark that "one general fact is, unfortunately, true of almost all cases, namely, that the palsy scarcely ever passes away entirely, and that where wasting occurs wasting remains."

During the stationary stage, whose duration is, upon an average, from one to six weeks, the paralysis, fully established at the end of the invasion stage, shows signs of diminution. Wasting of the muscles may now be observed, and they may give rise to pain upon pressure. Electrical treatment may be begun in this stage with advantage, and be continued through the next three. In fact, there is no disease of the cord in which more positive benefit is gained by persistent effort with electricity than this one; for in the atrophied muscles fibres seem to be affected with different degrees of severity, and a few often recover a

response to faradic irritability,—namely, a normal reaction,—and thus restore, if only to a limited extent, lost motions and avert more serious deformity.

Three pathological features confront us,—the destruction, partial or complete, of central spinal ganglionic cells; a degeneration of the nerves leading from the spinal centre, and a consequent atrophy of muscles innervated by these nerves. Treatment must, therefore, be directed to the muscles, to the nerve-trunks, and to the central lesion, named in an inverse order from the centre outward, in order to facilitate a localization of the local focal level of the cord attached by means of an electrical examination of the peripheral parts.

A special indication for the treatment of nerve-trunks as well as the muscles is the existence of pain upon movement of the limbs and tenderness upon pressure. Where this condition is well defined, neuritis undoubtedly exists. A mild galvanic current should be employed; a positive, indifferent electrode of large dimensions upon the sternum or other indifferent spot, and the cathode labile to the affected nerves and muscles. At the same sitting the cathodic electrode may be used for from five to ten minutes, of a current-strength easily borne (for in these cases what the little patient can be induced to bear, rather than the readings of the milliampère-needle, must be our guide), over the affected circumscribed area of the cord. The level and extent of this area may easily be determined by electrical examination of the muscles. (See table, p. 79.) Those in which atrophy has become established will exhibit the reaction of degeneration, more or less pronounced, according to the degree of the atrophy.

In severe cases, with much atrophy, the faradic excitability of the muscle, tested at its motor point, will be found to be entirely lost, some times even as early as the sixth or seventh day. This loss to faradic stimulation may never be restored, and in these cases—namely, of early and complete loss to excitability by faradism—we may feel assured that the wasting and paralysis will be permanent.

The behavior of other muscles to faradism will vary in ratio to the absence or to the degree of degenerative process. In the muscles not affected degeneratively the excitability is merely lowered, while in those not completely degenerated it is slowly regained; at least, in a certain number of individual fibres. It is this slow recovery of individual fibres of muscles which have lost their bulk, and which, in fact, will never regain it, that encourages the physician in the persistent use of faradization, even for two to three years.

The reaction of the wasting muscles to the galvanic current requires no special description; it is the usual "reaction of degeneration," and in those muscles which atrophy hopelessly beyond repair the voltaic response dies out from month to month and finally disappears.

The reactions of the muscles just described establish beyond

question the exact situation of the focal lesion. They are also thought by some to be a reliable guide as to the current which should be selected for permanent treatment. It is often advised, for instance, that that current be chosen which will produce muscular contractions. Of the two currents now under discussion, this, perforce, means the faradic current, or the *interrupted* galvanic. If the only result to be expected of electricity were to excite the contraction of the muscle, the advice is good; but if we hope to hasten the regeneration of nerve- and muscle- fibre by the influence of a specific polar quality of the continuous current, the advice is bad; for in the latter case an uninterrupted current is called for, and a special pole. Personally and from clinical experience, as well as from theories and facts regarding the action of the continuous current upon living tissue, I am satisfied that the cases of poliomyelitis in the second and third stages enumerated will do better by aid of the continuous current, negative pole labile to the extremities and stabile to the centres, than they will by constant stimulation of the already-exhausted fibres by faradism.

In chronic and later stages, where the active processes in cord, nerves, and muscles have subsided, and where the sole object can be to tease and urge fibres sluggish in their contraction to renewed activity, any interrupted current will accomplish the result, and the faradic, having no chemical action, would be preferable. But even in chronic cases, where an electrical examination of the wasted muscle affords no response, and the inference would, therefore, seem justifiable that the corresponding nerve-cells were completely destroyed, experience has taught that the muscle, daily and carefully treated by the interrupted galvanic current, has, after a considerable time, regained electrical excitability and a fair degree of voluntary power. In support of this position, Graeme M. Hammond (*Journal of Nervous Diseases*, January, 1893) reports three most interesting cases. In the first case, a lady aged 25 years had suffered, when 6 months old, an attack of poliomyelitis, which left her with the anterior tibial and peroneal groups of muscles paralyzed in both legs. As she grew older, both gastrocnemii contracted, giving rise to marked talipes equinus. On examination, the muscles in the right leg responded to the galvanic current, but not to the faradic. The contractions were, however, slight. In the left leg the peroneal muscles responded very slightly to galvanism, the anterior tibial muscles not at all. The tendons of both gastrocnemii were divided. On the left side the tibialis anticus and the extensor proprius pollicis responded faintly to will-power, and not to any form of electrical stimulation. Applications of galvanism (after what method is not stated) were made, for almost a year, both to the two *completely* paralyzed muscles and to the others. At the end of six months a faint reaction was exhibited in the left tibialis anticus. This became more noticeable, and finally could be induced by efforts of the will. The other muscles also

progressively improved. A little over a year after treatment began, slight contractions were observed in the left extensor proprius pollicis, and flexion of the left foot could be performed fairly well. At the date of the report the patient walked quite well, and without a brace of any kind.

In the second case, a lad aged 11 years had suffered from an attack of unilateral poliomyelitis when he was 6 years of age. At the time of examination the peroneal group of muscles and the tibialis anticus were totally paralyzed. These muscles could not be made to contract to the electrical current to the slightest appreciable extent. After seven months of daily applications faint contractions were observed in the tibialis anticus. These increased in vigor, and soon slight contractions could be induced by efforts of the will. But persistent treatment for one year and a half failed to arouse any electrical reaction in the peroneal muscles. In this case, also, the tendon of the gastrocnemius was cut.

In the third case, a boy of 9 years of age at 3 years of age had poliomyelitis. The tibialis anticus and extensor proprius pollicis would not react to the electrical stimulus. Daily applications were made, and at the end of five months slight contractions were observed in the tibialis anticus, and gradually voluntary control was fairly well established; the foot could be flexed, but the muscle never became what could be called strong. Eleven months' almost daily treatment to the extensor proprius pollicis failed to produce the slightest evidence of reaction.

Duchenne has carefully pointed out that a careful examination of chronic cases will often reveal, even after four to six years, a few remaining contractile fibres, and that, if the development of these fibres is fostered by faradization, an improvement in their bulk and voluntary movements may be obtained.

These cases are instructive as well as for what was not as for what was accomplished. Of two muscles which were apparently in an exactly similar condition of atrophy, one regains a partial power, while the other is irretrievably lost. They show that there comes a time to cease treatment as well as that it is difficult to decide when this time has arrived.

In thus faithfully treating affected muscles and nerves, as is frequently done, the effect of afferent neural impressions upon the gray cells must be kept in mind. It is quite as legitimate to suppose that some of the benefit derived from peripheral treatment is due to an arrest or improvement in the degenerating cells of the anterior horns as it is to believe that purely local changes in the nerve and muscle account for it. In fact, the former supposition is the easier to conceive of.

The varieties of "club-foot" which result from acute poliomyelitis are familiar. The muscular mechanism causing the deformity may be found in works on anatomy and surgery. In a recent case of talipes

equino-varus in a girl of 16 years, who had long worn orthopædic apparatus, the writer restored the patient to a perfect gait, without apparatus, after about two months, by powerfully faradizing the muscles antagonistic to the paralyzed group until they were exhausted and had lost, by excessive contraction, their muscular tone.

The usual course of treating cases of acute poliomyelitis is to begin as soon as the signs of the acute inflammatory stage are over; this is often as early as the second week. The directions given by Erb are to employ the galvanic current, stabile, upon the cervical or lumbar enlargements, or both. The site of the disease is covered with a large electrode, while the other is applied to the anterior surface of the trunk. With the electrode thus placed they are made, by the aid of the pole-changer, first anode and then cathode for one or two minutes each. If both enlargements are involved, an electrode is placed over each and the current alternated, as above, at brief intervals. The nerve-trunks and muscles are treated peripherally with a labile cathode, and the anode is placed over the site of the disease. Voltaic alternatives are recommended in the later stages of the disease.

As previously pointed out, the writer prefers the cathode stabile to the site of the disease, and labile or stabile to the nerve-trunks and muscles, and placing the anode at an indifferent point. This method has the advantage of consistency to specific polar effects, has been found to give excellent results, and, least of all, to produce no untoward effects.

Gowers recommends strongly the use of galvanization to the muscles, but solely to preserve their tonicity during the period that the influence exerted by their nerve-fibres is cut off. He says, "If the muscles are excited from time to time by electricity their sensitiveness to stimulation is distinctly increased, and this not only to electricity, but to voluntary stimulus. This is clearly shown by cases that have been untreated; the muscles may not respond at all to the first application, but when they have been galvanized two or three times a distinct contraction may be obtained, and, within a week, some voluntary power may return." The muscle is thus sustained in good condition to receive whatever nerve-power may be regained. The labile cathodic electrode should be lifted from the skin at each stroke, so as to produce gentle contractions of the muscle. Gowers does not believe that electricity can prevent or even lessen the visible wasting of the muscles, and states that there is no evidence that it can or does influence the process of recovery of the damaged elements in either the spinal cord or the nerves, or, indeed, that the cord is reached at all when one electrode of the galvanic current is placed over the spinal lesion; though in the next sentence he is of opinion that, used upon the skin over the muscles, "the diffusion of the voltaic current is so great that it is sure to reach the affected muscles." If the muscle is reached, why also is not the cord reached by a similar "diffusion"? And if muscles are caused to contract, muscular protoplasm and its modifi-

cations are caused to contract; and if it is good to cause the muscular protoplasm to contract in order to sustain its life and its function, why is it not equally good to cause nerve-protoplasm to contract in order to preserve its life and its function, so far as is possible, against the inroads of morbid attacks?

In the opinion of the writer, too much stress is laid upon the nerves as a medium of conduction of electrical stimulation to the various constituents of living tissue, cells, and fibres. For, though the excitability of the tissues is commonly set up by the intermediation of the nerves, it is also true that the tissues have an independent excitability. A colorless blood-corpuscle, a nerve-cell, and a secretory cell are independently excitable. In the same manner, a muscle, though its nerve be severed, or even after it has undergone fatty degeneration (Brown-Séquard) is also excitable. If, then, tissues (including nerve-tissue) are directly excitable by electrical stimulus, it follows that the chemical exchanges which constitute their living are influenced. The sole question is: Is this influence of advantage or of disadvantage of no effect upon the morbid process affecting the tissue?

As the science of electro-biology grows in accuracy, it is to be hoped, and by none probably more sincerely than the author quoted, that these questions will be settled affirmatively or negatively. In the meantime, and as long as electro-therapeutics is based largely upon clinical experience, as are most therapeutics, honest differences of opinion must continue to arise, and can with difficulty be impartially adjudicated upon. Medicine is not yet an exact science.

Spinal Meningitis (*Pachymeningitis*, *Leptomeningitis*, *Acute and Chronic*).—The sheaths of the spinal cord are subject to inflammation leading to both acute and chronic attacks. Meningeal inflammation affecting the dura mater may be either a *pachymeningitis externa* or a *pachymeningitis interna;* the former of infrequent occurrence, and caused mainly by caries of the vertebræ or tuberculosis, the latter of more frequent occurrence, and constituting a chronic disease marked by pain, paralysis of the arms and legs, atrophy, and contractures. The disease is often fatal, is sometimes arrested, and cures have been reported.

Both the central lesion and the peripheral regions may be treated by electricity, according to the general principles already outlined. Meningeal inflammation affecting the pia mater and arachnoid is termed leptomeningitis; it may be acute or chronic; both would seem to occur infrequently. For the chronic form electricity has been used, after the usual indications.

Specific directions are not called for in other diseases of the cord than those thus far mentioned.

In the pages which have preceded, the writer's intention has been to simply lay the subject of electricity in the treatment of spinal-cord

diseases before the reader as one of many therapeutic agencies which may be used to alleviate human suffering. If he has presented the subject from his own point of view it is because a compilation of methods, opinions, theories, speculations, cases, and results would have presented it from practically no point of view.

If he who would use electricity as a therapeutic agent in cord diseases is caused to pause and to study, rather than to make his applications hap-hazard, the writer will feel that the object of his contribution to these pages is fully attained.

ON THE USE OF ELECTRICITY IN THE TREATMENT OF DISEASES OF THE PERIPHERAL NERVES.

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This subject will be dealt with from the clinical stand-point only, the views herein expressed being the result of twelve years' clinical experience with this class of cases, and a knowledge of the labor of others in this field. Doubtless every application of the electric current to the human body calls forth a reaction in the organism. Thus far we know but little of its physiological effects. Whether its action is electrolytic, electrotonic, or reflex will not be discussed in this paper. A great diversity of opinion seems to exist as to the potency or impotency of electricity in the treatment of diseases of the peripheral nerves. It has recently been claimed that the improvement which follows its application is entirely due to "suggestion." The results, nevertheless, depend upon a definite method of application. Patients in general believe that the larger the dose the greater the benefit. In practice, however, we find that strong currents and long *séances* decidedly do more harm than good, despite the belief of the patient as to their greater efficacy. Where muscles are paralyzed owing to injury or degeneration of their nerve-trunks, improvement can almost invariably be demonstrated immediately after a suitable application of galvanism, although at times of transient duration. On the other hand, loss of muscular power becomes evident when the current has been too strong or unnecessarily prolonged in its application.

In our opinion, the so-called "suggestion" plays a very insignificant rôle in this class of cases. In young children the element of psychic influence may be safely excluded. In harmony with numerous observations (Bruns), paralyses of peripheral nerves resulting from pressure or injury, without external wound, may, by means of electro-diagnostic phenomena, be classified into three categories,—slight, medium, and severe. All of these forms can recover without electricity, but some of the severe cases do not get well under the most assiduous electrical treatment. From the changes in the irritability in the nerves and muscles, we are enabled to state almost accurately what the probability is as to recovery, and also the duration of the paralysis, without treatment:—

The *slight* form (without changes in irritability), about fourteen days. The *medium* form (partial reaction of degeneration), two months. The *severe* form (complete reaction of degeneration), three, to six, to nine months. The question, therefore, arises, Is this period shortened by

electrical treatment? In other words, can electricity (at least, in the second and third forms) hasten the process of regeneration? While it is a well-recognized fact that the peripheral nerves possess a remarkable inherent power of spontaneous regeneration, the statement has repeatedly been made that there is no evidence to prove that the application of electricity hastens the regeneration of peripheral-nerve structure. Having carefully observed and treated upward of three hundred cases of peripheral-nerve lesions, we feel warranted in assuming *that the process of regeneration is accelerated by the judicious use of the galvanic current.* This process is also influenced by the character and severity of the lesion, by the recuperative powers of the individual, and by the condition of the trophic centres.

In two cases whose pressure-paralysis is of equal severity the anatomical causes may vary considerably in intensity, so that the comparison of different patients, one of whom is treated by electricity and the other is not, cannot lead to any positive conclusion. The preliminary steps toward success in the electrical treatment of the peripheral nerves, particularly where paresis or paralysis is a prominent symptom, are a knowledge of the location of the principal so-called "motor points" and a correct interpretation of the various electro-diagnostic phenomena resulting from an examination of the nerve-trunks and muscles. Without such investigation a definite line of treatment cannot be instituted upon a rational basis. Comparatively little or no attention at all has been given, by the general practitioner, to the subject of electro-diagnosis. Too much stress has been laid upon the value of electricity as a therapeutic agent, while its importance in diagnosis and prognosis has been neglected. The degree of injury to the nerve-trunk may be determined (1) by its power to conduct sensory and motor impulses; (2) by its excitability to mechanical or electrical stimuli; (3) by the condition of the muscles in its anatomical distribution.

In cases of peripheral paralysis resulting from injury, such as pressure or traumatism, the electrical treatment may be begun in two or three weeks; for at this time we shall be able to determine approximately the extent of injury to the nerve, and also to express an opinion as to the prognosis. The beneficial effect to be derived from the use of the current in these cases cannot be attributed to any adjuvant method of internal medication. In cases of neuralgia, however, internal medication is of the greatest value. Prompt relief from pain is frequently obtained by galvanism independent of any additional form of treatment. There can be no doubt as to the efficacy of electricity in cases of ordinary neuralgia. In the peripheral forms it exercises a curative influence. In these cases nature has had ample time to display its reparative power. There are cases, however, of true neuritic neuralgia which, as a rule, subside without treatment. We are by no means sure, as yet, that all neuralgia depends on a neuritis. It is possible that electricity may relieve

or diminish the pain, while the pathological process is uninfluenced and runs its regular course.

As a general rule, the galvanic current is to be preferred. No standard of dosage can be formulated as to the current-strength required to produce contraction in paralyzed muscles. The invariable rule should be *to use the weakest current which will produce perceptibly active, but not violent contractions.* Owing to the variability in the resistance of the skin, due to variation in moisture and the degree of pressure of the electrodes, etc., uniformity as to the current-strength required cannot be expected. In some cases more satisfactory reactions may be obtained by stroking or interrupting with the anode than with the cathode. This generally occurs where the reaction of degeneration is present. When the muscles fail to respond either to faradism or galvanism, the galvanic irritability may be restored after a few applications of the sparks from a static machine. This favorable result does not always follow. Lesions of the olfactory and optic nerves are not amenable to electrical treatment.

PARALYSIS OF THE OCULAR MUSCLES.

Paralysis or paresis of the ocular muscles (motor oculi, trochlearis, abducens) is due either to peripheral or central causes. The treatment must depend upon the most exact diagnosis possible, concerning the form and distribution of the paralysis, and especially the localization of the lesion.

In those cases resulting from nuclear disease (ophthalmoplegia), or in the presence of tumor, syphilis, etc., little or no benefit can be expected from electrical treatment. It is only when the paralysis is due to refrigeration, or is rheumatic, or the result of slight traumatism, that the current seems to be of service. There is no electro-diagnosis of ocular paralyses, as the action of the current cannot be sufficiently circumscribed in order to produce isolated contraction of individual muscles.

The direct application of an electrode and the current to the ocular conjunctiva is a painful procedure, and is rarely tolerated by the patient. Since the use of cocaine it was hoped that electricity could be applied to the individual ocular muscles after producing anæsthesia of the surface of the eyeball, but this hope has not been realized.

It has since been suggested and advised, and also attempted, to pierce the conjunctiva with a needle attached to one of the poles of the battery, and thus apply the current directly to the affected muscle. This method has proved impracticable, and, even in the hands of an expert, is not unattended with danger to the delicate structures of the eye. This is particularly the case in the use of the galvanic current.

The writer has tested this plan of treatment in a large number of cases, and was obliged to abandon it, as it seemed to possess no superiority over the usual method of application, but increased the difficulties.

Moreover, nearly all of the patients were unwilling to further submit themselves to such a complicated course of manipulations. The application of the current to the eye must always be looked upon as a delicate procedure. Practical familiarity with the use of the galvanic current and a knowledge of the relationship between electro-motive force, resistance, and current-strength (Ohm's law) are absolutely essential in order to intelligently and safely apply this method of treatment. Indeed, it is even possible to injure the refractive media of the organ with too strong a current, and disagreeable results (sudden vertigo, headache, etc.) are known to follow any sudden increase or diminution in the current-strength.

The indifferent electrode (anode), three by four inches, is placed in position, either over the nucha or the sternum; the cathode over the closed eyelids. The latter, which is covered with sponge or absorbent cotton, is to be thoroughly moistened with warm saline solution, and retained in position by a bandage or gently moved over the surface (labile method). The current-strength may be from $\frac{1}{2}$ to 2 or 3 milliampères. The average is about $1\frac{1}{2}$ milliampères. After the electrodes are in position the current is allowed to flow and is gradually increased, by means of a rheostat in the circuit, until the patient feels a slight burning sensation over the eyelid. Before removing the electrodes the current should be slowly reduced to zero. The electro-motive force need not exceed 15 or 20 volts. Owing to the possibility of accident, generally from a defective rheostat, it is injudicious to have the full force of a battery representing from 50 to 100 volts in the circuit during the application of the current to the eyes, or, in fact, to any part of the head.[1] The *séance*, lasting from three to five minutes, should take place daily or every alternate day. The efficacy of this method of application in increasing the power in paretic ocular muscles, and thus aiding in the restoration of function, can be easily demonstrated by means of prisms. The measure of the strength of the recti muscles lies in the ability of the patient to neutralize the effect of prisms of varying degrees when placed before the eye in definite positions.[2]

NEURALGIA OF THE FIFTH NERVE.

The results of electrical treatment in the ordinary forms of neuralgia of the trigeminus are sometimes rapid and gratifying, while in the severer

[1] Several recent writers have expressed the opinion that the therapeutic effects may differ when we use the same current-strength derived from a varying electro-motive force. In other words, that the application of 2 milliampères with an electro-motive force of 20 volts differs from that of 2 milliampères from a force of 50 or 100 volts. (The resistance being controlled by a rheostat in the circuit.) Such a statement is contrary to the fundamental principles of electro-physics. The only dosage that we have to deal with is current-strength in milliampères, as indicated on the meter. Practically, all other factors are negligible. A current-strength of 2 milliampères is 2 milliampères under all circumstances, and is well known as the result of a definite electro-motive force overcoming a definite resistance.

[2] For further information as to the method of using prisms, the reader is referred to works on ophthalmology.

forms, such as tic douloureux, electricity, like everything else, proves inefficacious in most instances. Under treatment the pain rapidly and completely subsides, and when it recurs the application promptly relieves it. The general causes of trigeminal neuralgia are the same as the general causes of all forms of neuralgia. The passage of this nerve through bony canals, however, renders it very liable to be implicated in various affections of the bones and periosteum. Tumors which compress the nerve at the base of the skull also cause intractable neuralgia. Among other causes are peripheral irritations, such as carious teeth and diseases of the nasal and frontal sinuses. Various constitutional disturbances are also apt to bring on facial neuralgia.

For ordinary cases a weak current (1 to 3 milliampères), applied for five minutes several times a day, if necessary, will generally afford relief. The *anode* (diameter one and one-half inches) is placed successively on the points of emergence of the several branches of the nerve, the current being localized mainly upon the points. The *cathode* (four by four inches) is firmly fixed over the upper cervical vertebræ. The current must be regulated by means of a rheostat, and the application made according to the *stabile* method. Care should be taken to avoid interruptions in the circuit. In some cases relief is obtained by one application daily, for ten minutes, of a current as strong as the patient can comfortably tolerate. In others, faradization of the dry skin over the sensitive points with the wire brush frequently relieves the pain. The same general principles are to be followed in the electrical treatment of cases of neuralgia affecting the occipital cervico-brachial and intercostal nerves.

PARALYSIS OF THE FIFTH NERVE.

Paralysis of the trigeminus most frequently results from lesions within the pons, disease at the base of the brain (especially tumors), chronic meningitis and caries of bone. This conditon may also be caused by traumatic injuries, such as punctured or bullet wounds through the mouth and nose. Each division of the nerve has a course that exposes it to special lesions.

When there is anæsthesia without pain, the terminal sensory fibres may be stimulated. This can be accomplished by faradization of the skin. The faradic wire brush is most effective, and should be applied to the dry skin over the anæsthetic areas. The current should, if possible, be strong enough to produce some sensation, and may be applied for three or four minutes daily. When the temporal, masseter, and pterygoid muscles are paralyzed, the interrupted galvanic current may, in some cases, serve as an adjunct to other treatment in restoring power to these muscles.

FACIAL SPASM.

This is the most frequent, and practically the most important, form of spasm. It is also called mimetic facial spasm, or convulsive tic. The spasm may be tonic or clonic, or both combined. It is usually unilateral,

often extending over the whole distribution of the facial nerve, but sometimes confined to individual muscles. It may arise from various causes. In some cases, perhaps, the disease is to be referred to a lesion of the trunk of the facial nerve from exposure to cold, aural affections, disease at the base of the skull, or to a reflex irritation of the nerve in trigeminal neuralgia. Many cases are probably of cerebral origin, from an affection of the facial centre in the cortex. The following methods of electrical treatment have been recommended:—

The anode (a large flexible plate) is applied two or three inches above the ear, so as to cover the lower portion of the central convolutions, whilst the cathode is fixed to the nape of the neck. A weak current, from 1 to 5 milliampères, is then allowed to pass for five to ten minutes. The same application may be made also with the poles on the occipital region and the face, respectively. As in all applications of galvanism to the head, the current should be gradually and slowly made, and reduced to zero through the intercalation of a rheostat in the circuit.

Voltaic alternatives (sudden and repeated changes in the polarity) may be made with strong currents in the affected nerve and muscles. The strength of the current must be regulated according to the sensitiveness of the patient.

The facial nerve and muscles may be subjected to "swelling" faradic currents, *i.e.*, currents slowly brought up to the maximum strength tolerated, and very gradually reduced to zero. Any pressure-points over the area of the trigeminus and along the cervical spine should receive a weak, stabile, anodic galvanization or cutaneous faradization.

Although electricity has been used in every conceivable manner, it has proved absolutely inefficacious in the vast majority of cases.

PARALYSIS OF THE FACIAL NERVE.

We must differentiate between the type of facial paralysis accompanying the ordinary form of hemiplegia and that due to a lesion at the facial nucleus or in any part of the course of the nerve. The former is to be considered as of "cerebral" origin, while the latter is of "nuclear," or "peripheral" origin. In the cerebral form the upper branches of the facial nerve are rarely affected, the paralysis being limited to the lower half of the face, while the orbicularis palpebrarum escapes. The nerve and muscles continue to react to the faradic current, and usually there is a quantitative increase in their faradic irritability,—*i.e.*, it requires a weaker current to produce the same degree of muscular contraction than upon the healthy side. In peripheral facial paralysis, however, all branches of the nerve are affected, and the patient is unable to close the eye (lagophthalmos) or to wrinkle the skin over the forehead.

The faradic irritability is either diminished or lost within ten days or two weeks. In some cases, where the lesion in the nerve is very slight, the faradic reaction may be preserved, but it invariably requires a

stronger current to produce the same degree of contraction upon the paralyzed side than on the healthy side (quantitative decrease). In others, where the nerve-trunk is seriously involved, at the end of two weeks the nerve has lost its electrical irritability and reacts neither to faradism nor galvanism; while the muscles fail to contract to the strongest faradic current, but react upon the application of a weak galvanic current slowly interrupted.

In addition to this, we may find that the reaction is greater at the closure of the circuit at the positive pole, or, in other words, that the anodic closure contraction is greater than the cathodic closure contraction (A. C. C. $>$ C. C. C.), which is a reversal of the normal formula. This condition, in addition to the slow and protracted character of the muscular contraction, constitutes what is known to-day under the name of reaction of degeneration (R. D. or De. R.).[1]

The presence of R. D. is conclusive proof of the existence of a lesion of some severity at the nucleus or in the course of the nerve-trunk. In two cases of complete peripheral facial paralysis, which present exactly the same appearance under similar clinical conditions, the degree of injury to the nerve and the prognosis can only be determined after electrical examination. As a rule, in order to determine approximately the degree of injury to the nerve, ten days or two weeks should elapse before electrical treatment is instituted. In case the faradic irritability be preserved at this time, the probability is that recovery will take place without treatment. Yet, if the motility in the facial muscles is absolutely abolished, no harm can occur from the daily application of a weak faradic current just sufficient to produce muscular contractions. Sensory faradic irritation has, perhaps, a favorable influence, since it produces a reflex irritation of the motor nerves. In the presence of R. D. it is obvious that the galvanic current should be used exclusively. In these cases of facial paralysis the error is frequently made in applying the faradic current, which seems to be absolutely useless, as it fails to produce any reaction in the facial muscles.

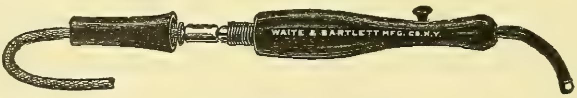
Physicians who are practically unfamiliar with the clinical use of electricity seem to possess the idea that our treatment and the selection of the form of current to be applied is limited to that which causes the most marked muscular contractions. No doubt this view would hold good and prove of practical value in many of these cases, were it not for the fact that the contraction of the masseter and pterygoid muscles (and thereby the slight movement propagated to the facial muscles by contiguity) is so frequently mistaken for contraction of the muscles innervated by the facial nerve.

In facial paralysis the masseter muscle is not involved, being supplied by the motor branch of the trigeminus. Thus, patients have been subjected to the painful application of a strong faradic current daily, for

[1] See article on "Electro-diagnosis."

months, without the slightest benefit. We must always bear in mind that, even in the worst cases, a certain amount of improvement will take place spontaneously, despite the most irrational methods of treatment. This improvement usually begins in the upper facial muscles, *i.e.*, in the orbicularis palpebrarum and the corrugator supercilii. The method of application is as follows: The electrodes (two inches in diameter) and face being thoroughly moistened with warm water, the *anode* is placed either over the stylomastoid foramen or in the fossa below the ear. The *cathode* is held in position over the various branches of the nerve in turn (stabile method), and a current of about 2 to 4 milliampères allowed to pass for one minute at each point. The strength of the current must be graduated according to the sensations of the patient.[1]

Each group of muscles is then made to contract by the interrupted galvanic current, by using an electrode with the handle so constructed as to permit of the opening and closure of the circuit without its removal from the surface of the skin.[2] The entire *séance* should last about ten minutes daily, or every alternate day. This electrode may also be utilized



DIAGNOSTIC ELECTRODE.

for diagnostic purposes (see cut), and possesses the following advantages over those now in use:—

1. All of the connections are completely insulated, thus preventing the accidental closure of the circuit upon the fingers of the examiner.

2. The shape of the interrupting handle adapts itself to the fingers and hand of the operator.

3. The curve in the shaft attached to the "motor point" facilitates its adjustment and manipulation.

There is a thread cut on the end of the handle, where the conducting-cord is attached. This permits of a hard-rubber cup being screwed on, which entirely covers the connection.

AUDITORY NERVE.

According to Erb, Brenner, de Watteville, and others the healthy acoustic nerve reacts in a definite manner to anodic and cathodic excitations. If a medium-sized electrode be placed just in front of the ear, so as to cover the tragus (but *not* to close the meatus), it will be found

[1] A case of facial paralysis was recently reported by Minkowski (Berlin. klin. Woch., 1891, No. 27) in which the nerve-trunk was found normal, although all of the symptoms pointed to a lesion in the region of the geniculate ganglion. The pathological changes were limited to the peripheral branches. Death was due to accidental injury. It would seem, therefore, that in some cases the current may act directly *in loco morbi*.

[2] It was described by the writer as "an improved form of diagnostic electrode," in the New York Medical Record, January 21, 1893.

that the healthy nerve reacts only to cathodic closure and anodic opening. The indifferent pole is placed in the hand or over the sternum. The reaction consists in a sound variable as to its pitch and duration. It may be of a ringing, hissing, humming, or buzzing character. Experiments on the electrical reaction of the acoustic nerve offer certain difficulties. Many individuals require such strong currents to elicit a response that the vertigo and other unpleasant symptoms accompanying such excitations preclude us from obtaining on them satisfactory results. In others, however, the acoustic reactions are elicited with weak currents, and may, therefore, be studied in detail. The symptoms which call for galvanic treatment are deafness and tinnitus, due respectively to anæsthesia and hyperæsthesia of the nerve. In nervous *tinnitus* the reactions of the nerve are probably always abnormal. The indications for the treatment are derived from the respective influence of the anode and of the cathode on the subjective sounds, that pole being applied to the ear under whose influence the noises are found to diminish. In certain cases complete silence is produced, especially by the anode, for a longer or shorter time. Many of the ill successes which have, in the hands of aurists, attended the galvanization of the acoustic nerve would seem to be due to the very defective methods employed. In order to make the diminution of the tinnitus persist after the removal of the electrode, it is indispensable that the latter should be removed only when the current has been reduced to zero by imperceptible degrees. This is an impossibility with the usual batteries without the intercalation of a rheostat. The strength of the current should be such as to check the tinnitus, if possible, without producing much giddiness, and the application be protracted to ten minutes or even longer.

The plan for the treatment of nervous *deafness* consists in excitations of the nerve with a galvanic current in which interruptions or voltaic alternatives are made. The precautions for gradual diminution of the current are, of course, unnecessary, but the mode of application otherwise remains the same as for tinnitus. When the latter co-exists with deafness, and is relieved by the current, according to the method described above, both are usually found to disappear at the same time (de Watteville).

Various forms of aural electrodes have been used, such as a special aural electrode insulated by a rubber speculum-tube, which is inserted into the external auditory meatus and filled with warm water. This possesses no special superiority in its results over the external application of the electrode.

SPINAL ACCESSORY NERVE.

Spasm of the Sterno-cleido-mastoid and Trapezius.—Spasmodic action in the domain of the spinal accessory nerve may be either tonic or clonic in character, or these conditions may co-exist. The clonic form

of spasm is usually the predominant element. The sterno-cleido-mastoid muscle is the more frequently affected, but the trapezius is often simultaneously involved. With unilateral affection of the sterno-cleido-mastoid the head is jerked backward and to one side, the chin being turned toward the opposite side and raised, and the occiput drawn backward.

If the trapezius (upper portion) be alone affected, the head is drawn backward and toward the same side without rotation of the chin. The head is sometimes drawn backward with great force, so that the occiput and shoulder almost touch. If both muscles are coincidently affected, the two movements are combined or alternate with one another. The spasm may extend to the other muscles of the neck, and occasionally both sides may become involved.

It is probable that the muscular contractions depend on the overaction of nerve-cells, and not on any irritation of nerve-fibres It seems doubtful whether we have at present sufficient evidence to justify us in coming to any conclusion regarding the seat of the disease. Electricity has been used in various ways in the treatment of this affection, but only in rare instances has it proved more than palliative. The frequency and severity of the spasm have been temporarily ameliorated, but no cures have been reported.

The galvanic current may be applied (as in facial spasm), the anode to the parietal and occipital regions of the head and the cathode over the affected muscles, the *séance* lasting five to ten minutes daily. The various peripheral modes of electrization recommended for facial spasm may be brought successively into use if necessary. Some writers have advised the application of faradism to the group of muscles on the opposite side with the object of increasing their power, thus endeavoring to establish equalization in functional activity. This method may be discarded as both irrational and inefficacious.

Nerves of the Upper Extremity.

THE BRACHIAL PLEXUS.

The *brachial plexus* may be the seat of neuritis due to constitutional causes or the result of traumatism, and may be attended with severe pain. Paralysis of the muscles in the distribution of the affected branches frequently follows.

The condition known as Erb's paralysis is a form of paralysis in one arm, occurring most frequently in infants from injury to the fifth and sixth cervical nerves by forcible traction on the head and neck during delivery. In the adult it may arise after injury to the neck, either from a fall or a blow. It may also occur spontaneously after exposure to cold. The muscles paralyzed are the deltoid, biceps, brachialis anticus, infraspinatus, and supinator longus, and occasionally the extensors of the hand. These two nerves, owing to their superficial position in their

exit between the scaleni muscles, are especially exposed to injury. This form of paralysis is as amenable to electrical treatment in infants as in the adult.

Although spontaneous recovery has been known to occur in some instances, it is hardly safe to delay electrical treatment beyond six weeks. We have, however, seen infants with this form of paralysis, when over a year old, recover completely under a systematic and prolonged course of electrical treatment. Galvanism is to be used. Children tolerate relatively stronger currents than adults without evidence of pain. One electrode (three by four inches) is placed over the lower cervical vertebræ and the other in the axilla, and a current of 3 or 4 milliampères allowed to pass for about five minutes.

Each paralyzed muscle is then made to contract by the labile method, the weakest current being used that will elicit a perceptible contraction. The *séance* should last about ten minutes every other day. In the adult a similar course may be adopted, the time being prolonged to fifteen minutes and a stronger current used in the first half of the sitting. Neuritis and paralysis of the brachial plexus in all of its branches may arise in the adult, either spontaneously or from traumatism. In some cases of neuritis the pain is extreme and is not ameliorated by the use of the galvanic current.

CIRCUMFLEX NERVE (PARALYSIS OF THE DELTOID).

Injuries to the *circumflex nerve* may result from dislocations and falls on the shoulder, and from the pressure of a crutch. It may also be affected by a simple neuritis, the result of rheumatism. It suffers with other nerves from disease of the upper part of the brachial plexus. The chief symptom is paralysis of the deltoid. The upper arm cannot be raised to the horizontal position.

After the stabile application of about 5 milliampères for three or four minutes, the muscle is stimulated to contraction by the labile or the interrupting method. Each segment of the muscle should receive attention, the arm being supported in the horizontal position, *i.e.*, at right angle with the body. When the muscle reacts to faradism this current may be used, although, as a general rule, galvanism is to be preferred.

THE MUSCULO-SPIRAL NERVE.

The *musculo-spiral nerve* is more frequently paralyzed alone than any other nerve of the arm. It supplies the triceps, all the muscles on the back of the forearm, the extensors of the wrist and fingers, both the supinators; also the skin on the radial side of the back of the hand, the back of the thumb, index finger, and half of the middle finger.

The frequency with which this nerve suffers is due to its course. Its position exposes it to injury from fracture of the humerus, in dislo-

cation or pressure from a crutch, from callus, and from temporary pressure during sleep. The latter is the commonest cause, particularly during alcoholic sleep. This form of paralysis can be readily recognized, since the hand hangs down, relaxed in a flexed position (wrist-drop) owing to paralysis of the muscles on the extensor side of the forearm. When wrist-drop is present on both sides, it is most frequently the result of lead poisoning.

The treatment must be guided by the result of the electrical examination. In mild cases the faradic irritability may be preserved, although diminished. In all, the use of the galvanic current is preferable. The same general rules are to be followed as in the treatment of other forms of peripheral paralysis. When the paralyzed muscles do not react to faradism and nerve degeneration is present, its persistent use may be prejudicial to the case (1) by strengthening the opposing flexor group and thus hastening deformity by undue overaction of these healthy muscles, and (2) by failing to stimulate to contraction the paralyzed muscles. The stabile galvanic current (3 to 5 milliampères) is to be applied for five minutes over the point of injury, the size of the electrodes being three inches by four inches. One electrode is to be placed over the anterior surface and the other over the posterior surface of the arm. All of the affected muscles are then made to contract separately by the labile or the interrupting method, the indifferent electrode being held in position above the point of injury. During the application the hand should be supported, in order to avoid tension upon the extensors of the wrist and fingers. This manipulation also aids in the extension of the fingers during the electrical reaction. The *séance* should last about ten minutes daily or every alternate day, according to circumstances.

THE MUSCULO-CUTANEOUS NERVE.

The *musculo-cutaneous* nerve is hardly ever paralyzed alone, but often suffers with other nerves in disease of the brachial plexus. The biceps and brachialis anticus are paralyzed. The forearm, when in supination, cannot be flexed, but in pronation the supinator longus can still display its action of flexion. The action of supination by the biceps, which it exerts when the forearm is flexed, is also absent. The electrical treatment requires no special description.

THE ULNAR NERVE.

The course of the *ulnar nerve*, being superficial behind the elbow and at the wrist, renders it liable to separate injury. It is occasionally the seat of neuritis, and, like the musculo-spiral nerve, it is sometimes paralyzed by pressure. Ulnar paralysis arises chiefly from traumatic influences. Flexion of the hand is interfered with, and especially its lateral movement to the ulnar side (flexor carpi ulnaris). Flexion of the last three fingers is imperfect from partial paralysis of the flexor

profundus digitorum, and the little finger cannot be moved at all (hypothenar muscles). Owing to paralysis of the interossei, flexion of the primary phalanges and extension of the terminal phalanges of the fingers become impossible. There is difficulty in spreading the fingers and bringing them together again. The thumb cannot be firmly adducted against the metacarpal bone of the index finger (adductor pollicis). In almost all old cases of ulnar paralysis, a characteristic position of the hand is developed. This is known as the "claw-like hand," or "*main en griffe.*" At this stage electrical treatment is useless. During the early period, when pain is present, the galvanic current (stabile) may afford relief, the *anode* being applied at various points along the course of the nerve, and the *cathode* in the axilla, or over the seventh cervical vertebra. Two to five milliampères are usually sufficient, the *séance* lasting about five minutes. When there is paralysis, the application (stabile) is to be made over the seat of the lesion, one pole on the anterior and the other on the posterior surface of the extremity. The current-strength is to be as much as can be comfortably tolerated for three minutes. The muscles of the forearm are then to be separately stimulated to contraction by the labile application. Unfortunately, in many instances, the treatment of the small muscles of the hand has been neglected. The thenar and hypothenar groups and the interossei should receive careful attention. By means of a small electrode attached to the interrupting handle, each muscle is made to contract. Five minutes are quite sufficient for the entire hand. Great care is to be observed to avoid overstimulation and consequent exhaustion. For the anæsthesia the faradic wire brush will prove invaluable. This application should be the preliminary step in the treatment. The skin having been wiped dry, some starch-powder is dusted over the surface and the electricity applied, as strong as tolerated, over the anæsthetic area for about two minutes. The other electrode (three inches by four inches) may be placed at any indifferent point. In some cases the sensibility is permanently restored after two or three applications.

THE MEDIAN NERVE.

Isolated palsy of the *median nerve* is not frequent, and generally results from wounds of the forearm. The nerve is occasionally the seat of neuritis from compression. It frequently escapes in neuritis or injury of the brachial plexus. Pronation of the forearm is almost wholly abolished (pron. rad. teres and quadratus). The hand can be flexed only toward the ulnar side by the flexor carpi ulnaris, owing to paralysis of the flexor carpi radialis. The terminal phalanges of the fingers can no longer be flexed (flex. sublim. dig. and a part of the profund.), but flexion of the primary phalanges is normal by means of the interossei. The patient can grasp an object only by the last three fingers, which can still be partly flexed by the flexor profundus digito-

rum (ulnar n.). The thumb cannot be flexed or opposed (flex. long. poll. et brevis; opponens), and usually lies on the hand. In the electrical treatment the same method is to be adopted, with but slight variation, as in paralysis or neuritis of the ulnar nerve.

Nerves of the Lower Extremity.

Disease of these nerves is more uncommon than those of the upper extremity, with one important exception,—the primary disease of the sciatic nerve, known as "sciatica." The vast majority of cases of sciatica are really cases of neuritis of the sciatic nerve. Rheumatism and gout are the chief constitutional states in which it is developed, while as exciting causes may be mentioned exposure to cold; mechanical causes, such as pressure of the edge of the chair in those who sit much. Rectal and other tumors, pelvic inflammation, and injury during labor are occasional causes. It may result from disease of the bone, especially disease of the hip-joint.

PARALYSIS OF THE SCIATIC NERVE.

This nerve may also be paralyzed as a result of spontaneous degenerative neuritis, or from dislocation of the hip-joint or other injuries. Walking is still possible, as the power in the quadriceps is not interfered with. In addition to the symptoms mentioned under the head of "Paralysis of the Peroneal and Tibial Nerves," there is inability to flex the leg backward on the thigh. This is due to paralysis of the biceps, semitendinosus and semimembranosus. There may also be extensive anæsthesia along the course of the cutaneous branches.

In the *treatment* large electrodes are to be used (five inches by five), one being placed over the lumbo-sacral region and the other below the sacro-sciatic foramen. The patient should be in the recumbent position, the weight of his body keeping the electrodes in contact with the skin. The galvanic current (stabile), from 15 to 30 milliampères, is to be used daily for five minutes. All of the paralyzed muscles are then made to contract by the labile method. The faradic wire brush is also applied to the area of anæsthesia, according to the method mentioned under the treatment of paralysis of the ulnar nerve.

PARALYSIS OF THE PERONEAL AND TIBIAL NERVES.

The branches of the sciatic nerve which are at times separately affected are the external popliteal or peroneal nerve and the internal popliteal or tibial nerve. The *external popliteal* nerve may be the seat of neuritis from pressure during sleep, or the nerve may be injured by a fall or dislocation. This results in paralysis of the tibialis anticus, extensor longus digitorum, peronei, and extensor brevis digitorum. The condition is at once recognized by the flaccid drooping of the foot. Dorsal

flexion of the foot and extension of the toes are impossible. The foot cannot be raised from the ground in walking, and talipes equinus ultimately results.

Treatment.—One electrode (four inches by four inches) is placed over the outer aspect of the popliteal space, at the origin of the nerve, and the other a few inches above the patella. Stabile application, 10 to 20 milliampères, from three to five minutes. The foot being supported at right angle with the leg, the paralyzed muscles are stimulated to contraction, for about five minutes, by the labile method. In the presence of anæsthesia the faradic wire brush is to be used.

Disease of the *internal popliteal* nerve paralyzes the popliteus, calf-muscles, tibialis posticus, and the long flexors of the toes, as well as the muscles of the sole. Plantar flexion of the foot becomes impossible. Adduction of the foot and plantar flexion of the toes are also abolished. Talipes calcaneous results. The *treatment* is similar to that of the external popliteal, with the additional application to the small muscles of the foot. The plantar nerves rarely suffer alone.

SCIATICA.

Next to trigeminal neuralgia, neuralgia of the sciatic nerve is by far the most frequent, and practically the most important, form of neuralgia. In contrast to most of the other neuralgias, it is more frequent in men than in women. Cold, wet, and overexertion of the leg are found to be the most frequent etiological factors. More rarely venous stasis in the pelvic veins (hæmorrhoids) and habitual constipation give rise to the development of sciatica. We see symptomatic neuralgia in the region of the sciatic nerve in pelvic tumors, caries of the sacrum, and analogous affections. Other traumatic influences and compression of the nerve, as in constant uncomfortable sitting, are sometimes evident causes of the disease. Pressure of the gravid uterus on the sciatic plexus may sometimes excite sciatica, and in women it has occurred as the result of delivery by forceps.

The pain is in the distribution of the sensory branches of the nerve. There is at first a feeling of heaviness and tingling in the leg, which aches and becomes tired after slight exertion. When the pains begin they are lightning-like or tearing. They either come on in characteristic neuralgic paroxysms or they are more continuous, and are then described by the patient as "burning," "boring," and the like. They are often worse at night. Movement of the limb increases the pain, and sometimes the sensitiveness is so great that the slightest motion excites the severest pain, and the affected leg is kept quiet in a slightly-flexed position. The pain is usually felt at the back of the thigh down to the popliteal space. The outer surface and dorsum of the foot may also be affected. Painful points are often found along the course of the sciatic, over the gluteus maximus or at its lower border, in the popliteal space (tibial nerve), at

the head of the fibula (peroneal nerve), at the malleoli, on the top of the foot, etc. A slight atrophy of the muscles often develops, but the higher degrees of atrophy indicate that there are serious anatomical changes in the nerve.

Treatment.—With the patient lying on his back, a large, flat electrode (five inches by five inches) is placed over the sacrum or lower lumbar vertebræ, and retained in position by the weight of the body. The other electrode (of the same size) is adjusted at different points along the course of the nerve. The current, being controlled by a rheostat in the circuit, should be allowed to flow without interruption. The lower electrode is preferably applied over any tender points that may exist, and gradually, by a sliding movement, its position may be changed. The current-strength is regulated according to the sensations of the patient. From 10 to 20 milliampères is usually well borne, the *séance* lasting from five to ten minutes. This application is made daily or every alternate day. It is almost invariably followed by increased warmth in the limb and by relief of varying duration. Frequently the relief becomes permanent. The position of the poles seems to make no practical difference in the result, although it is customary, upon theoretical grounds, to apply the anode over the painful points. Where signs of muscular atrophy or weakness are present, a gentle labile application may be made to all of the affected muscles. In some cases the faradic wire brush, applied to the dry skin, has been known to permanently relieve the pain.

THE ANTERIOR CRURAL NERVE.

This nerve is sometimes damaged during parturition, and where the the lumbar plexus has been invaded by inflammation. It may also be injured by wounds of the groin or thigh or by dislocation of the hip-joint, or it may be the seat of neuralgia symptomatic of pelvic trouble. The chief symptom of disease of this nerve is the loss of power in the extensors of the knee and the wasting of these muscles, together with loss of the knee-jerk which results from interruption in the reflex arc. The thigh cannot be flexed on the trunk, and the trunk cannot be raised from the recumbent position. Walking and standing are very difficult or almost impossible.

In the electrical treatment the same rules are to be observed as have been described under the management of sciatica and sciatic paralysis. The paralysis accompanying the various forms of multiple neuritis requires no special description. The current may be utilized in the manner outlined in the foregoing *résumé*.

ELECTRO-THERMAL SURGERY.

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Galvano-cautery.

Long before the discovery of Volta or the experiments of Galvani, and soon after the introduction of the Leyden jar, the calorific effects of electrical discharges through good conductors were known and investigated by Franklin, Bacaria, Van Marum, and others. As a matter of history also, and in proof of the advances made at an early period in this new field of scientific research, it may be of interest to state that by the aid of a powerful electrical machine in the Tyler Museum, at Harlem, Van Marum was able to fuse an iron wire fifty-two feet in length. It is more than doubtful, however, if this remarkable quality of electric discharges could ever have been put to practical use, or in any material way benefited mankind or the arts, had it not been for the discovery of Volta.

Soon after the introduction of the pile it was observed that a continuous current, in its passage through metallic conductors, also possessed heating properties, and to an equally remarkable degree. Metallic wires of every kind, including gold, could not only be rendered incandescent, but even fused, and, what was of greater importance, without the explosive phenomena which attended electrical discharges. Thus was opened up a new and attractive field for scientific cultivation, and, as its first fruits, laws were formulated by which this peculiar character of the voltaic, galvanic, or continuous current was found to be governed.

The experiments of Fourcrouy, Vacgulin, and Thenard in France, and Cuthbertson and Sir Humphry Davy in Great Britain, during the first quarter of the present century, have always attracted the attention of philosophers and students in this department of electro-physics. So exhaustive, indeed, were the experimental researches of these philosophers that it may be safely asserted that, except as to adaptation and matters of detail, our knowledge regarding the generation of electric energy and its transformation into heat was as complete three-quarters of a century ago as it is to-day. And yet, strange as it may appear, nearly fifty years elapsed before it occurred to any one that this extraordinary force might be turned to profitable account by enabling surgeons to perform safe and bloodless operations, and often under circumstances where no other effective means could be thought of.

Previous to 1850 the usual, if not the only, purposes for which galvano-cautery was employed were the destruction of dental nerves, the removal of small excrescences, the obliteration of birth-marks, and the

cauterization of fistulous channels. In 1851 Ellis, of London, first suggested a spiral cauterizer by winding a few inches of the platinum wire around the stem of a clay pipe; and soon after Marshall in England, and Middeldorpf in Germany, simultaneously, though independently, were the first to devise the cautery-loop carrier, by which warts or other outgrowths could be encircled and removed. In 1854 Middeldorpf published his report of still more important cases treated by him, and from this period up to 1870 the field for this new and bloodless method of conducting surgical operations steadily broadened, and the practice became quite popular, particularly with leading gynæcologists. In 1872 a monograph by the writer, entitled "Clinical Notes on the Electric Cautery in Uterine Surgery" appeared. In addition to a record of cases treated, this brochure contained instructions as to the care and management of such batteries as were then in use, and certain rules were laid down to be observed in the technique of operations. At that time it was remarked that "any one who might desire to obtain useful information or definite rules and directions which would enable him to operate successfully by means of the electric cautery would search in vain among the gynæcological records or other medical literature,—in our language, at least." Also, "that many of the unsuccessful, perhaps clumsy, attempts to operate by galvano-cautery of which we hear—as, for example, when the battery is said to have given out at a critical moment—have been due less to an imperfection in the apparatus than to a want of experience or an inadequate knowledge of electro-physics on the part of the surgeon. It will be found impossible to construct any galvanic or other philosophical apparatus which may not occasionally become defective, either by accidental displacement of some of its parts or imperfections resulting from use."

The fixed and immutable laws by which galvanic power is to be generated and utilized demand not only the strictest observance, but also a reasonable degree of adroitness in manipulation and that ready dexterity so often found to be the surgeon's "friend in need." Though certain rules may be laid down regarding general management of batteries and the proper manner of conducting cautery operations, yet nothing short of a tolerably exact scientific knowledge of the subject will enable an operator to overcome obstacles oftentimes unavoidable. In works on natural philosophy the subject of electro-physics is necessarily considered in a too cursory and general manner to be of much practical value, and even writers on electro-physics have felt constrained to refer in almost equally general terms to a surgical measure about which few only can speak from extended clinical observation. As to text-books on diseases of women, their authors for the most part barely concede to galvano-cautery a qualified approval by placing it in the list of means "which may be employed" under certain circumstances. No allusion whatever is made to the laws under which chemical action in a cell or battery is transformed

into current and heat, and no explicit directions regarding the technique of operations are to be found. Under such circumstances the student or practitioner, as the case may be, if he should not be fortunate enough to have closely observed the methods of some one skilled in such operations, must find himself as a mariner without a compass. It is doubtful, therefore, if any surgical measure of equal importance, ancient or modern, has been so generally misunderstood and so persistently misrepresented by writers on diseases of women as galvano-cautery.

The benefits derivable from galvano-cautery properly employed may be enumerated as follows: (1) the avoidance of hæmorrhage, primary and secondary; (2) exemption from sepsis and its dangerous complications; (3) its germicidal effects on deep-seated tissues far beyond the cauterized surface, as in cancerous infiltrations; (4) the power of controlling and limiting its field of action in delicate and out-of-the-way cavities and parts; (5) unlike every other form of actual cautery, it is free from the destructive effects of radiant heat on adjacent healthy structures; (6) it is the only means known by which a continuously heated wire may be made to surround and remove tumors or to destroy pyogenic membranes of fistulous canals.

It is hardly necessary to remark that if the advantages here set forth and claimed for galvano-cautery are well founded,—and the writer believes and knows they are,—gynæcologists who still continue to disregard or ignore clinical facts of such vital importance assume a moral responsibility for which there is no excuse or warrant.

EXPLANATIONS AND EXAMPLES OF THE CALORIFIC EFFECTS OF THE GALVANIC CURRENT IN METALLIC CONDUCTORS.

The subject of electro-physics has been so fully considered elsewhere that it will not be necessary here to do more than refer briefly to some leading phenomena connected with the heating of platinum wire by the galvanic current. It would be well, however, though not essential, for the reader to study carefully and grasp the meaning, bearing, and application of Ohm's law, the general principles involved in the development of galvanic energy and the various directions in which its transformation may be effected, as in electrolysis and the production of heat, light, and dynamic force.

With regard to the laws of the transmission of galvanic currents, it may be remarked that an absolutely perfect conductor does not exist. Even virgin silver and pure copper are found to offer a certain degree of resistance. It is usual, however, to consider as good conductors such as are found to offer but little resistance to the passage of the current, and which, consequently, favor the production of certain electro-dynamic phenomena, as heat, light, and electric disruption. As to the cause and source of heat in a galvanic circuit, it may be stated that the energy in

any cell or battery is due to the fact that when the circuit is closed one of the elements, zinc, previously amalgamated, is acted upon and dissolved by the exciting fluid. If the terminal or conducting wires be thick and short, thus offering little or no resistance to the current, energetic chemical action, and at the same time the development of heat, will be observed in the cell or battery. That this heat should be confined entirely to the cell in this case is explained by the fact that the conducting power of the thick and short wires is so great that no resistance is offered to the current, and consequently no external heat is developed. In fact, the only resistance met with in the entire circuit is in the stratum of fluid which interposes between the zinc and the negative plates and the elements themselves. Hence, the development of heat in the cell will be directly proportionate to the conductivity, and inversely as to the resistance in the external circuit. In other words, with a closed short circuit, energy due to the combination of the zinc and acid is spent in the development of heat in the battery and the kinetic force of the current. If, now, the two conducting wires be separated, and a thin platinum wire, which is an imperfect conductor, be interposed in the circuit so as to offer a comparatively great resistance to the current, a large portion of the heat, which in the first instance was developed in the battery only, will at once be transferred to the resisting platinum wire. Moreover, the lessening of the heat in the battery will be found to be directly proportionate to the length—that is, the resistance—of the interposed wire.

As a further illustration of the same law, and as regards the transformation of electro-chemical energy, it may be added that if a very long and fine wire of any metal be interposed in a circuit so that its resistance shall be very many times greater than the electro-motive force (the *vis a tergo*) of the battery, the heat therein developed may be hardly observable,—partly owing to radiation, but also, and mainly, because the kinetic energy of the current has been spent in the work of overcoming resistance. By electrolysis also, as elsewhere fully explained (see A–272), we have another example of a transformation of chemical energy in a battery in which the work of tearing asunder two substances in chemical combination, as in decomposing water, interesting examples of which may be found at A–273. Our present purpose, however, concerns but one of the many phases of this subject, namely, the production of heat in platinum wires interposed between two conductors of little resistance. The following examples, having a direct bearing on the application of galvanic heat to surgical uses, will be found to possess practical interest.

Under whatever form heat is produced by a galvanic current, one condition will be found necessary for its manifestation, namely, that the current in its course through the metallic conductor must meet with a resistance, and where this resistance is greatest the heat will be most intense.

Examples.—1. If to the conducting cords of a battery of sufficient power we attach two wires in succession of equal length and diameter, one of copper and the other one of iron, it will be found that the iron will become red-hot while the copper will be but moderately warm.

2. If for the iron a wire of pure silver—which is the best metallic

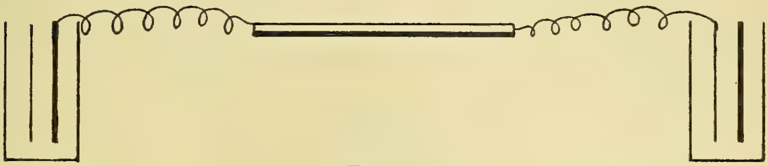

FIG. 1.

conductor—be substituted, the copper, as it offers a greater resistance, will become heated.

3. If a chain of three or more wires of silver and platinum, or copper and platinum, alternately arranged, be interposed in the circuit, the platinum may become almost incandescent, while the silver and copper will be barely, if at all, warm.

4. If two platinum wires of the same length, but different in thick-

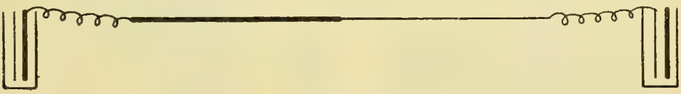

FIG. 2.

ness, be introduced,—one being, say, one-fiftieth of an inch in diameter and the other twice as thick, or one-twenty-fifth of an inch, and placed parallel to each other in the circuit (Fig. 1),—the larger of the two, which transmits the greater quantity of electricity and presents a cooling surface much less in proportion to its volume than the finer wire, will have a more elevated temperature while thus united; but if these same wires are united end to end, the finer wire will become red-hot (Fig. 2).

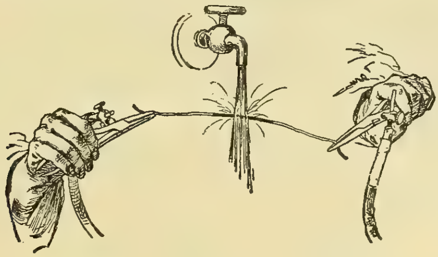

FIG. 3.

5. If a platinum wire—say, one-thirtieth of an inch in diameter and twelve inches long—be brought to a dull cherry-red heat, and a stream of cold water be made to flow over a space of two or three inches of its centre, the wire on either side of the cool portion will become incan-

descent (Fig. 3). This experiment proves what the laws of electric conductivity teach: that while heat in any part of a metallic conductor increases its resistance, by cooling a part of the wire—say, one-third—the latter becomes a better conductor, and most of the current, at first distributed over the entire length, is now employed in heating two-thirds only.

6. In further illustration of the electro-physical laws of resistance and conductivity, if, as in the previous experiment, the wire be brought to a red heat, and while in this condition the flame of a spirit-lamp be made to play upon any considerable portion of it, the temperature of the outlying part will at once become lowered and the redness disappear. In this case the resistance of the superheated portion of the wire is immensely increased, and hence a large part of the volume of current is retarded and, as it were, absorbed, and consequently transformed into heat (Fig. 4).

With these familiar examples and a *little* knowledge of electro-physics in general, which in this exceptional case would not be dangerous, it is hoped that what may be said under the head of "Cautery

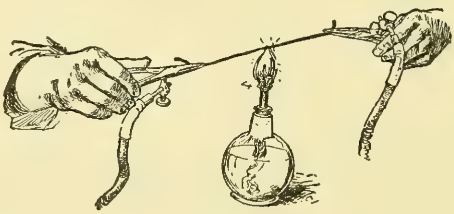

Fig. 4.

Batteries" will be the better understood. The main object in view here is to present the subject in as plain, brief, and intelligible a manner as possible, and free from all unnecessary technicalities; hence, many interesting points and references are purposely omitted.

Some acquaintance also with that branch of physical science which treats of force and the transformation and conservation of energy would, doubtless, tend very much to make plain many phenomena which, at first sight, might seem inexplicable; hence, any surgeon who might desire to study and investigate this subject in a manner most profitable, most agreeable, and least arduous, will do well to consult the text-books.

Cautery Batteries.

The subject of batteries in general has been so fully discussed elsewhere that nothing need be added here beyond what concerns those designed exclusively for the generation of heat in metallic conductors.

During the first few years following the introduction of galvano-cautery the most available, if not the only, form of battery employed was

that of Grove & Bunsen, either of which, however, though amply powerful, presented so many objectionable features that they soon gave place to the more simple form of single-fluid battery as devised by Wollaston shortly after the introduction of Volta's pile. This change was first rendered possible through the adoption of carbon as a negative element instead of copper or silver, both of which would be acted upon by the stronger acid solutions, and especially by those containing bichromate of potash. All batteries, therefore, up to 1875, constructed for cauteri-

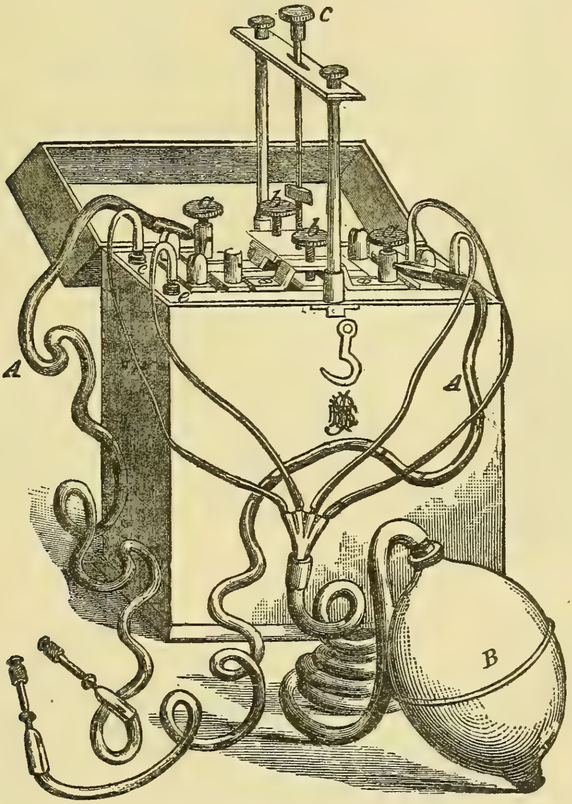

FIG. 5.—CAUTERY BATTERY. (Waite & Bartlett Mfg. Co.)
A A, conducting cords; *B*, pneumatic agitator; *C*, suspension rod and connecting set-screw combined; *a a*, poles of battery; *b b*, set-screws to couple for quantity; *e e*, air-tubes.

zation, contained plates of carbon and zinc, which were found, when immersed in bichromate solutions, to generate an electro-motive force almost equal to either of the two first named. Soon after the discovery of a metallic negative conductor (1876), designed to take the place of carbon in single-fluid batteries, it was proposed to substitute a sheet of platinum instead of carbon, and to overcome the difficulty of polarization by a mechanical device for removing nascent hydrogen from the platinum surface. Two forms of apparatus con-

structed in this manner are already familiar to many, and are known as the Dawson and Piffard batteries. So far as a means provided for keeping the negative surfaces free, nothing better could be desired; and as a high electro-motive force could be thus obtained, these batteries answered fairly well for short operations. As might have been anticipated, however, in prolonged use or when the circuit had been closed for any length of time, as in most cautery operations, the heat generated in the battery was found to be so great as to cause the fluid to boil over and destroy carpets and other articles of furniture. With any such arrangement there is no possibility, short of the suspension of all electro-physical laws, of obtaining any better result, as a very little reflection on what has already been said regarding the calorific effects of the galvanic current will explain. This resisting platinum plate, being part of the circuit, must, as a matter of course, add to the internal resistance of the cell or battery, become intensely hot, and, consequently, convey to the fluid in which it is immersed an enormous amount of heat, which is thus frittered away in a most objectionable direction. A due appreciation of this difficulty led the writer to undertake an exhaustive course of experi-

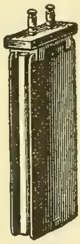

FIG. 6.

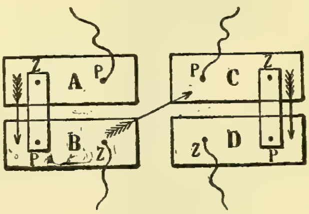

FIG. 7.

ments nearly twenty years ago, the result being the construction of a battery which, since 1876, has been used by him, to the exclusion of all others, in many hundred operations. The negative elements are made by soldering to one face of a copper plate, previously protected by an envelope of thin sheet-lead, a sheet of thin, yet compact, platinnm foil, the edges and back of the copper, as already stated, being protected by sheet-lead. The platinum surface is then either electro-coated by black platinum or, what seems to answer nearly as well, gently rubbed over in all directions by a piece of fine emery-paper. Each cell of the battery has one zinc plate interposed between two such surfaces (Fig. 6).

It will be observed that this apparatus may be considered as made up of two batteries of two cells each (Fig. 7), the negative and positive elements in A and B and C and D being permanently united. If the positive element (zinc) in B be united to the negative in C, p in A and z in D will be the poles of a battery of four cells. If the contact between z in B and p in C be broken, and p in A be connected with p in C and z in B with z in D, we obtain a double volume

of current at the expense of one-half the electro-motive force derivable from four cells in series. With the first arrangement fifteen inches of looping wire—say, No. 20—may be brought to a red heat, and with the second at least twelve inches of No. 16, the one giving a current of great intensity, which is required for a long, thin wire, and the other a greater volume of current, which is suited for heavy instruments, as dome-shaped cauterizers and the like. The manner in which this change from quantity to intensity and *vice versâ* is quickly effected will be understood by referring to the diagram representing the platform with its metallic connections (Fig. 8).

The mechanism of this apparatus as a whole, and the means by which these changes from intensity to quantity, and *vice versâ*, are effected, will become still more manifest by referring to Fig. 4. By the set-screws *b b* the two poles, *P P* and *Z Z*, are joined, thus converting the battery into one of two double cells; while, if *b b* be released and the suspension rod *C* screwed down, the battery will represent four cells in series; in either case the poles will be the same. The explanation of

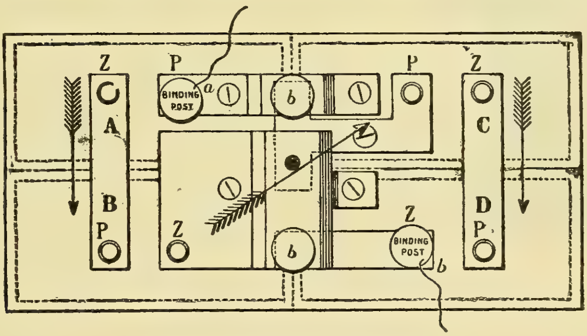

FIG. 8.—DIAGRAM OF PLATFORM.

the extraordinary power obtainable from this arrangement lies in the fact that, by the peculiar construction of the negative plates, while we obtain the high electro-motive force of a platinum-zinc combination, we have, at the same time, the conductivity of copper; and, as a consequence, no internal resistance to the current, except what is offered by the thin stratum of fluid between the elements. By actual measurement the internal resistance of each cell is less than $\frac{1}{15}$ ohm, while the electro-motive force reaches nearly 2 volts,—a result never heretofore attained by any galvanic pair in bichromate solutions.

In 1890 the writer exhibited a yet simpler form of battery, constructed on the same principle, and, by invitation of Professor Pozzi, operated with it at the Lourcine-Pascal Hospital, in Paris. It consists of plates arranged for two cells, but, as in Faraday's experiments, batteries thus arranged may be plunged into one vessel, instead of separate cells. Though the former apparatus leaves nothing more to be desired, so far

as completeness and efficiency are concerned, yet the latter, though perhaps equally expensive, is less complicated, exceedingly small and portable, and sufficiently powerful to meet every emergency. When used with two cells, such as those employed in the larger battery, no more than seven ounces of fluid should be poured into each; but, as before stated, it may be immersed to a proper extent in a single vessel of any size, when an unusually protracted operation is to be undertaken. The writer, however, would recommend recharging the cells as the exciting fluid becomes exhausted, and, as one charge will be found sufficient for an operation of fifteen minutes' duration, a second will rarely be needed. The box containing it is three and a half by three and a half, and seven inches high.

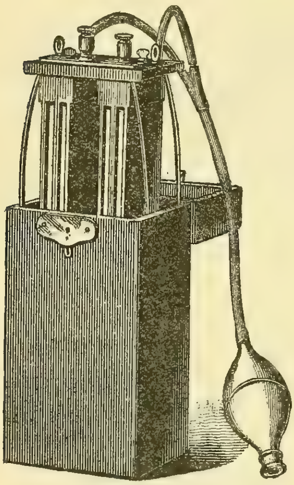

FIG. 9.

DIRECTIONS FOR SETTING UP THE BATTERY.

The quantity of fluid needed to charge the larger apparatus is two pints, or eight ounces to each cell. This fluid is prepared by mixing, in a suitable vessel, one part by measure of strong, commercial sulphuric acid with five parts of water, and adding to each pint of such mixture two ounces of crushed bichromate of potash. The fluid should not be used until it cools. In operations of short duration, or where the heavier instruments are not to be used, equal parts of this fluid and water will be found quite strong enough. Every galvanic battery, of whatever construction, should be carefully examined each time before commencing operations, so as to make sure that in transportation, or from any other cause, the metallic connections on the platform have not been disturbed or any of the zinc plates twisted so as to be in contact with the negative plates. Before pouring the fluid into the cells the battery should be lifted out carefully and allowed to rest on some level surface. The next step will be to screw on the two upright posts and, by means of the centre rod passed through the transverse beam and screwed into its proper place, the battery is to be raised and suspended, as shown in the cut. When a long, thin wire is to be heated, as in looping, screw down the suspension-rod *C* firmly, and raise *b b* by a few turns; when a thick wire or heavy cauterizer is to be employed, release *C* by a few turns and screw down *b b* firmly. By the first proceeding a battery of four cells in series may be obtained, and by the second one of two cells of double-volume capacity. (See Figs. 7 and 8.)

The conducting cords, which should be six feet long, consisting of

from one hundred and twenty to one hundred and fifty copper wires of No. 30 gauge, bunched together, *but not twisted*, and covered with silk or worsted material, may be now adjusted, care being taken that the binding-screws are turned down firmly. It is quite important to see that not only the polar but all other connections, including those in the electrode handle, should be perfect. The pneumatic agitator should be worked, when needed, by short and frequent compressions of the bulb rather than by forcible and prolonged insufflation. Before commencing operations, and in order to be sure that all is right, one of the knives had better be connected and the battery immersed to test its capacity. In operating, the degree and volume or quantity of heat required may be regulated by the depth of the immersion, the strength of the exciting fluid, or the air-bulb. In nearly all cautery operations, except those in which the loop alone is used, repeated interruptions will necessarily occur; as, for example, in changing the form of knife or other instrument, and sponging the parts, etc. During every such interval, however brief, the battery should be raised so as to save the useless waste of zinc and deterioration of the exciting fluid. The reason for this precaution will be obvious when we bear in mind that, though amalgamated zinc in dilute sulphuric acid may be considered passive so long as the circuit is open, yet it is violently attacked by bichromate solutions whether the circuit be open or closed.[1] By observing this important fact one charge of fluid may be made to last through the most tedious operation.

After each operation the battery should be thoroughly washed by holding it under running water, when practicable, and should not be put into the box until quite dry. A new battery should never be used a second time without having the zincs re-amalgamated. This second amalgamation will be much more enduring, as the mercury penetrates the zinc more deeply than on the first application. The most convenient way to amalgamate the zincs will be to immerse them in a 10-per-cent. solution of sulphuric acid for a few minutes, then pour over each a sufficient amount of mercury to cover the surfaces and edges of each plate, and stand them on end to drain.

In addition to such instruments as are usually employed in utero-vaginal operations, as speculum, retractors, etc., the following will be sufficient to meet all ordinary demands:—

A diverging vulsellum (Fig. 10); two forceps with binding-posts for attaching the conducting cords, as in operations for fistula (shown in Figs. 3 and 4); one dome-shaped cauterizer (Fig. 11); one cauterizer for cervical canal or urethra (Fig. 12); one or more platinum knives (Figs. 13 and 14); one angular knife for kolpocystotomy (Fig. 15); one universal handle (Fig. 16); one loop-carrier (Fig. 17); fixation forceps for kolpo-

[1] By actual experiment, one of these zinc plates alone, immersed in ten ounces of ordinary bichromate solution, will raise the temperature of said fluid from 70 to 110 degrees in thirty minutes.

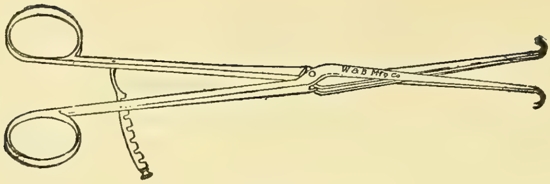

FIG. 10.

FIG. 11.

FIG. 12.

FIG. 13.

FIG. 14.

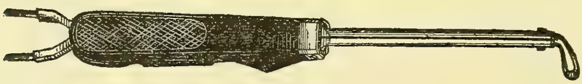

FIG. 15.

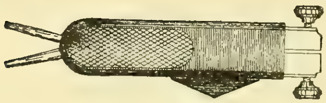

FIG. 16.

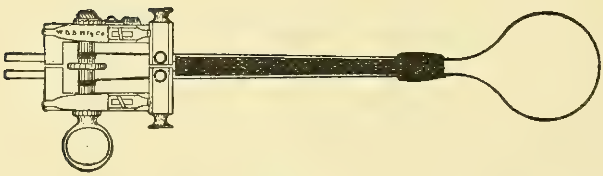

FIG. 17.

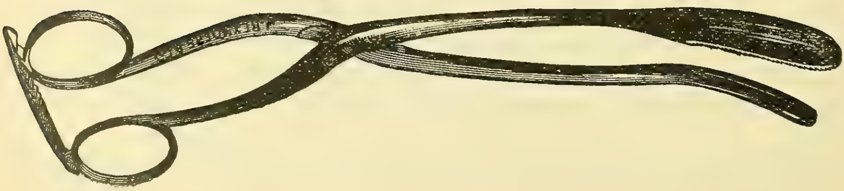

FIG. 18.

cystotomy (Fig. 18); some extra looping wire; one small cutting pliers; one small screw-driver; one small file; and a piece of steel wire for removing or turning down the binding-posts (*a*, *a*, Fig. 5).

In the foregoing remarks it is proper to state that, for the sake of brevity and to avoid confusion, it has been deemed best to confine the discussion of electro-physical laws within the narrowest possible limits. Consequently, such matters only as have a practical bearing on the main subject have been touched upon. What has been said, however, though cursory and general in character, may serve to convey a sufficient knowledge of the principles underlying galvano-cautery to render its study less irksome and, in its clinical aspects, more attractive and satisfactory.

DIRECTIONS FOR OPERATING.

Among the various diseased conditions for which galvano-cautery has been successfully employed may be mentioned the following:—

1. Extirpation and destruction of cancer and cancroid of the uterus and other parts within and about the genital tract, including epithelioma of labia.

2. Uterine polypi and sessile intra-uterine fibroids.

3. Vascular and other tumors in and about the urethra, and granular urethritis.

4. Hæmorrhoids and rectal prolapse.

5. Perineal, rectal, and vaginal fistulæ.

6. Vaginal and uterine prolapse, particularly in the aged.

7. Amputation for elongation and for areolar hyperplasia of cervix.

8. Kolpocystotomy for drainage.

9. Incising dense and vascular adhesions, and the cauterization of pedicles. For the latter purpose the more clumsy thermo-cautery may be made to answer, *provided healthy parts can be protected from the disastrous effects of its radiant heat.*

In operating by galvano-cautery for uterine cancer the mode of proceeding will vary to some extent, according to the leading features of each particular case, depending mainly, first, on the primary seat of invasion; second, on the extent to which the disease is found to have progressed; third, as to whether the vaginal or other outlying structures are involved.

Regarding the extent to which excision of the diseased part as well as the subsequent dry-roasting of its exposed seat must be carried, there should be no limit beyond what a due regard to the integrity of the adjacent organs would suggest. Where the disease would seem to be confined strictly to the portio vaginalis,—for example, in so-called cauliflower or vegetating epithelioma, and even true carcinoma in its early stage,—it was formerly deemed sufficient to remove the part by the cautery loop alone, steady traction being maintained during the passage of the heated

wire. It is true a deeply-concave stump resulted from such manœuvre, and in this class of cases relapses have been rare and exceptional. Nevertheless, it will be better to excise by the cautery knife (Fig. 14) close up to the vaginal junction. Should there be good reason to believe that no part of the upper cervical canal has been invaded, the circular

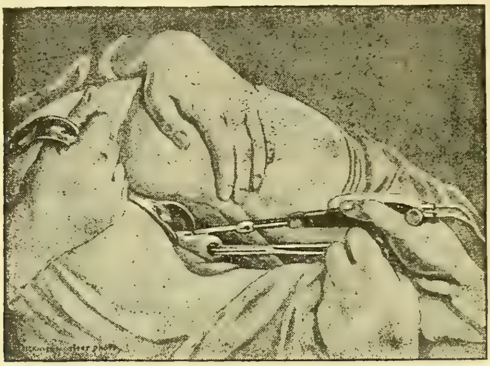

Fig. 19.

incision directed obliquely upward to the depth of a quarter of an inch or less may be made (Fig. 19), the platinum loop adjusted in the fissure, and while traction is kept up by means of the diverging vulsellum (Fig. 10) the operation may be proceeded with more expeditiously in this manner

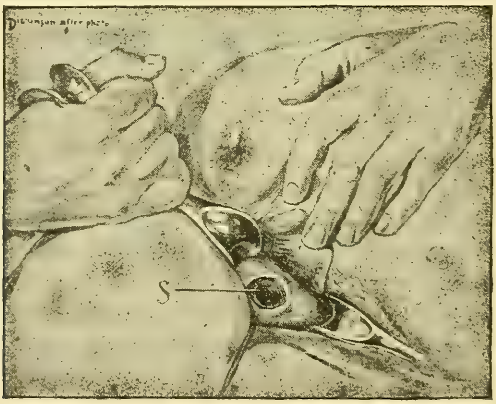

Fig. 20.

than by the use of the cautery knife exclusively. In either case subsequent cauterization should not be omitted, more particularly toward the centre of the stump and within what may remain of the cervical canal proper. For the latter purpose the spiral electrode (Fig. 12) should be employed. A correct representation of the stump after such an operation is seen in

the drawing from a photograph (Fig. 20). It should not be forgotten, however, that the cases are comparatively rare in which the simple procedure just described will suffice, as the entire cervix up toward and even beyond the *os internum* will be found to be involved in the vast majority. Consequently, unless the strongest evidence exists favoring an intact condition of the upper cervix, it will be wiser to amputate or excise higher up.

After all, the safest and most conservative rule to observe, in every case of well-marked cancer of the cervix, however circumscribed or limited it may appear, will be to include in the excision the *os internum*, and even a portion of the corpus.

It will be found that after the circular incision has been made and the uterus thus released from its vaginal moorings the degree to which it may be drawn down by moderate traction will be surprisingly great, and, as there need be no hæmorrhage, the extent and thoroughness to

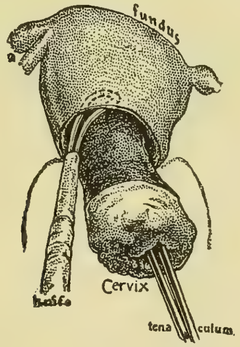

FIG. 21.

which conical excision may be carried has often astonished those who have witnessed high amputations by galvano-cautery. Fig. 21 shows the effect of traction after circular incision.

It is to be regretted that, of all cases of uterine cancer met with in hospital clinics or even in private practice, but a comparatively small number, perhaps about 15 per cent., can be satisfactorily treated in the simple manner above described. In not less than 25 per cent. the entire cervix will be found affected, and the parametric or vaginal tissues more or less infiltrated; often, too, while the uterus appears to be free and movable in all directions. One of the more frequent stages in which the disease is first brought to our notice is that in which the cervical canal, being the primary seat of invasion, has been transformed into an irregularly ulcerated and bleeding crater, whose zigzag edges appear as if retracted and drawn upward and into the diseased cavity. Or, if the denser structures have become infiltrated at an earlier period the entire portio will be found much enlarged, knobby, and indurated. Or, again, one or other lip only

may apparently be involved, and in which case the disease will usually be seen to have encroached upon the rectal or vesical wall, while the opposite side would seem to have escaped, as if the disease in sparing a part had directed its entire pathological force in another direction.

Another class of cases is to be met with in which the vagina is largely occupied by a soft, friable, and bleeding cancerous mass, or an enormously large and indurated cervix (Figs. 22 and 23). In such condition it will be found impossible to form a correct idea as to the extent to which the disease may have invaded the uterus until the obstructing mass has been first removed by the cautery loop, the sharp curette, or both. This having been effected, the upper vaginal walls previously hidden should be carefully examined and any suspicious-looking nodules

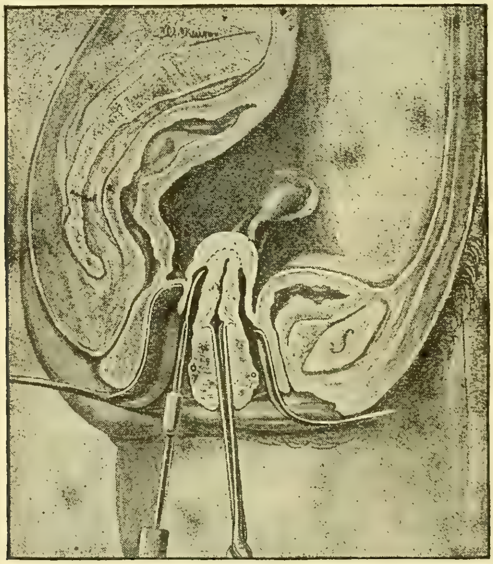

FIG. 22.

thereon removed by cautery knife and thoroughly cauterized. Should it be found that the disease in the posterior lip has involved the *cul-de-sac* of Douglas to a degree sufficient to warrant its excision and consequently opening into the peritoneal cavity, this had better be made the final proceeding in the operation. If carefully done, no evil consequences whatever may be anticipated therefrom, an antiseptic tampon to prevent intestinal protrusion being sufficient to meet the emergency (Fig. 24). The depth of the uterus should now be taken, what remains of the canal forcibly dilated and scraped out by sharp curette, and the uterine cavity, if necessary, submitted to the same process. The diverging vulsellum is next to be introduced, expanded, and locked, so as to secure complete control of the uterus, and the latter should be drawn down and

elevated alternately so as to accurately mark with the eye the line of vaginal insertion anteriorly and posteriorly. Having settled this important point, the knife, slightly curved and cold, is to be laid on the part to be incised, and the battery lowered slowly at first so as to guard against too rapid a development of heat. In a moment, however, as the knife becomes imbedded in the moist, submucous tissues, a greater degree of heat will be required, and may be intensified by the aid of the pneumatic agitator, but each time that the instrument is removed from its contact with the cauterized fissure the current should be broken, preferably by raising the battery. No more pressure should be made on the knife than is necessary to pass it through the tissues as severed, but

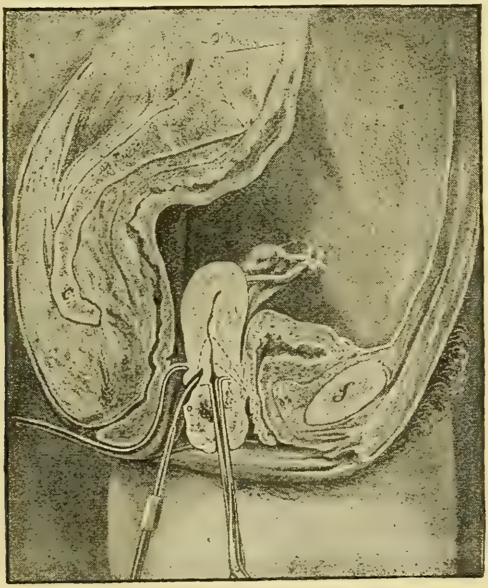

FIG. 23.

a to-and-fro rocking movement from heel to point of the heated blade will materially hasten the work. Extirpation of any considerable part of a cancerous uterus by the cautery knife is necessarily, and ought to be, a very slow operation, and will usually occupy from one-half to three-quarters of an hour. It is, therefore, better, in any case similar to that represented in Fig. 22 or 23, to remove the lower section by the loop when about half cut through all around, and thus obtain room and increased facility for the most difficult and important part of the operation. At this juncture, owing to the shriveled condition of the stump, it may be necessary to forcibly dilate the upper cervical canal so as to admit the sharp curette. This should be done carefully by the aid of the screw-button alone, and *not by unguarded stretching*, which might result

in tearing the tissues to an unlimited extent and opening into the peritoneal cavity. The curette should now be applied unsparingly, but by quick tractions of the instrument, care being observed to avoid that degree of pressure which might have a gouging effect, and thus provoke troublesome hæmorrhage or injure comparatively healthy structures in an unnecessary and very undesirable manner. The diverging vulsellum should now be passed into the uterine cavity proper, and by firm traction the concave stump may be made more or less convex, and the operation of excision proceeded with as in the beginning, care being taken to keep within safe anatomical bounds. Finally, the excavation is to be swabbed out, the dome-shaped instrument (Fig. 11) freely applied,

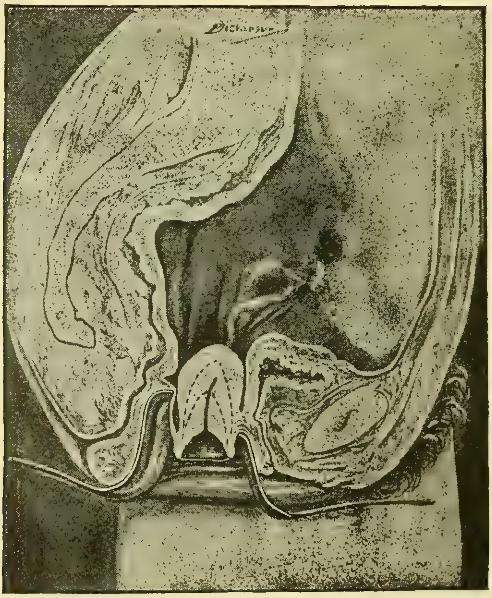

FIG. 24.

especially to the extreme upper part or bottom of the cavity, and a properly-formed tampon of suitable size, saturated with the antiseptic astringent solution (page 23), introduced and supported with one of dry antiseptic cotton in the vagina. These should be allowed to remain for forty-eight hours, when they may be removed carefully and replaced by others, but saturated with a solution one-half the strength of that used in the first instance. On the removal of the tampons at the expiration of the fourth or fifth day, the case will take care of itself, and nothing more need be done than syringing the parts with a 3- or 4-per-cent. solution of carbolic acid twice a day.

Uterine polypi and other pedunculated tumors require no special directions for their removal. It will be well to bear in mind, however,

that if the attachment of the pedicle should happen to be at or near the fundus, and especially where the tumor has already been expelled from the uterine cavity, the greatest care should be observed to make sure that partial inversion may not have taken place. Otherwise the temptation to sever the connection up as high as possible might lead the operator into a grave and perhaps fatal error. The following extract from the writer's notes will exemplify this important clinical lesson :—

A tumor was found to be firm and lobulated, and in size about twice that of a closed hand. Its pedicle, which measured about four inches in length, was round, and about one inch in diameter at its smallest part, which appeared to be midway between the tumor and its uterine attachment. Affixed to the pedicle, about one and one-half inches from the tumor, was a small fibroid outgrowth.

On attempting to pass the sound into the uterus, which appeared fully dilated, it was found impossible to carry it beyond one inch anteriorly, and less than half this distance either behind or in a lateral direction. A finger passed into the rectum came in con-

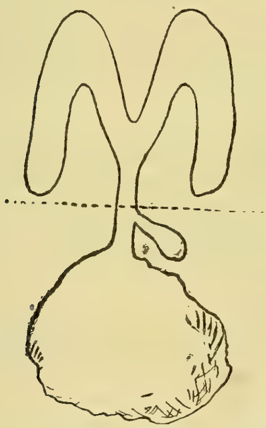

Fig. 25.—Fibrous Polypus; Uterus Partially Inverted.

Fig. 26.—A Sloughing Fibroid Producing Partial Inversion.

tact with a firm body as far as could be reached, and conjoined pressure over the pubis failed to convey any very definite idea as to the form or position of the fundus. Nevertheless, partial inversion of the uterus was diagnosed, or rather surmised, and, accordingly, instead of proceeding to sever the pedicle near what seemed to be its uterine insertion, the point selected was one-half inch above the little secondary outgrowth. When the heated wire had passed through and the tumor was removed, the uterus was found to have reverted itself, and the cavity measured over three inches in depth.

Many cases similar to the above are to be met with in gynæcological practice, and might be cited as showing not only the necessity for great care in diagnosis, but demonstrating in a convincing manner the advantages of the galvanic loop over all other means for the removal of tumors of this class.

Several examples of polypoid fibroids plus partial inversion of the uterus have been encountered by the writer, in which, had any other means

been resorted to, the most grave, if not fatal, consequences must necessarily have ensued. For example:—

Mrs. E., aged 43, multiparous; menstruated regularly and normally up to the age of 40, when the courses became more excessive and prolonged, and within a year thereafter there was but little interval between the successive and sometimes alarming attacks of hæmorrhage.

For a time she submitted to the consoling assurances of her friends, who pointed to the usual bugaboo, "change of life," as the sole cause of her trouble. Soon, however, she sought medical advice, and underwent physical examinations by a number of general practitioners, most of whom noticed the existence of a tumor of some kind, while some looked upon it as an inverted uterus; but, toward the end of the second year, though the hæmorrhages became less, yet offensive discharges were so abundant that the unanimous verdict was "cancer."

Upon digital examination the vagina was found to be entirely occupied by a tumor, which was soft and ragged at its lower or presenting surface, but gradually feeling more and more firm as the finger swept around its upper connection, and around which the dilated rim of the cervix could be mapped out. The sensation conveyed to the finger was that of two tumors divided by a deep fissure, or united by the shortest possible pedicle. A sound could be passed within the cervix in all directions to the extent of less than an inch, but the most careful rectal and supra-pubic explorations failed to detect a depressed or cupped fundus. Nevertheless, the diagnosis arrived at was: *a sloughing fibroid attached to the fundus, and producing partial inversion.*

The galvanic loop was adjusted with some difficulty, at the point of constriction, and the attachment slowly severed by the heated platinum wire. The sound could now be passed to the extent of three inches, and by upward pressure *per vaginam* the uterine body could be distinctly felt above the pubes. The cavity was douched with a 5-per-cent. solution of carbolic acid, and ʒss of Squibbs's fluid extract of ergot administered. No further treatment seemed indicated, and in two weeks the patient was discharged from the hospital perfectly well.

More or less sessile intra-uterine fibroids are occasionally met with in which some special device will be found indispensable. The following, in the hands of the writer, has served the purpose admirably:—

A, *B*, *C* (Fig. 27) are three hard-rubber crochet-needles, suitably curved, rounded at the ends, and each having a small hole drilled transversely,—say, one-eighth of an inch from its extremity,—and through which the platinum wire passes. The loop thus armed should be carried to the base of the tumor at its upper or more distant part, and there held by the centre rod in the hand of an assistant, while the loop-carrier fixes the wire at a directly opposite point of its connection with the uterine walls. By means of the two free rods the wire is now to be carried along the sides of the tumor to a suitable distance, and there maintained by another assistant, while the loop is moderately tightened. All being ready, the battery is to be immersed, the loop further tightened, and in a minute or less it will have cut through the rubber guides and become imbedded in the entire circumference of the tumor. The rods may now be removed and the operation proceeded with. The time necessary to complete the operation will, of course, depend altogether on the size of the tumor, but, as it must be considerable in any case, the metallic parts of the electrode should be covered with thin flannel, so as to protect the

vagina as well as the uterus from injury through reflected heat. No more strain should be put on the loop than is absolutely necessary to maintain it in close contact with the tissues, nor should the ratchet be turned but at intervals as each stratum is cut through. There need be no apprehension regarding the future disposition of the base of any such tumor after removal by the galvanic loop.

Epithelioma and other malignant growths on the external genitals should be removed in the following manner: While firm traction by means of vulsella is made, so as to draw the diseased part upward from its deep connections, a sufficiently long but slender trocar and cannula, slightly curved, is to be passed entirely through the base of the mass about its centre. The trocar is now to be withdrawn, a platinum wire, *much heavier than that used for looping*, is to be passed through the cannula, and the latter also removed. By means of the forceps electrode (Figs. 3 and 4) the wire should now be firmly grasped at a point

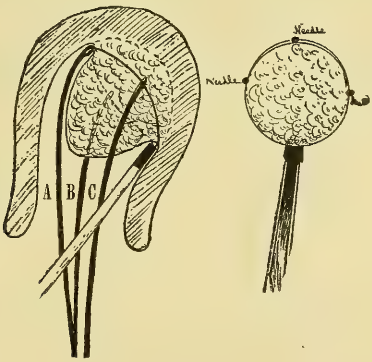

FIG. 27.

about an inch external to the tumor on either side, and the battery circuit closed. For a moment cauterization should be confined to the bed of the wire alone, so that, in the event of any large vessel having been transfixed by the trocar, there shall be no hæmorrhage then or subsequently. Traction on the diseased part being still kept up, the heated wire is to be drawn to and fro as often as its exposed extremity assumes a cherry-red heat. This see-saw movement is to be directed alternately to each half of the mass until a considerable portion of its base has been severed, when the glowing end of the wire, each time that it is drawn through, should be made to pass in a circular course and outside the supposed area of disease. This proceeding may be continued to the end; or, at a juncture when the grasp of the wire having become shorter and the right- and left- hand forceps approximate closely, the excision may be completed by the cautery knife. In the latter case the incisions should be made from without inward; but no operation of this nature can be

considered complete until the entire surface from which the diseased mass has been removed has been gone over and over again with the dome-shaped electrode.

Cases of this character are not infrequently met with where the disease is so extensive and the parts so enormously infiltrated and swollen that the operation is one of considerable magnitude, and may call for a second charge of fluid for the battery. In one case, three-quarters of an hour hardly sufficed to remove a cancerous labium and clitoris.

Vascular tumors in and about the urethra need no special directions for their removal, as each case will suggest the most appropriate method of proceeding.

In *granular urethritis*, the bladder having been emptied and the urethra dried by absorbent cotton, the pipe-stem electrode is to be inserted to a suitable distance, cold, and the battery connection effected. A few seconds at most will be sufficient to complete this operation, and from the time the instrument becomes hot until its removal from the urethra it should be constantly rolled half-round and back.

Hæmorrhoidal tumors, when isolated, may be clamped and removed by the cautery knife, the incised stump or edges being subjected to extra cauterization before removing the clamp; and the latter should be

FIG. 28.

allowed to remain a few minutes after completing the excision, and its grasp released slowly and carefully, so as to avoid hæmorrhage. When the tumors are large, and occupy the whole or a greater part of the circumference of the anus, the manner of proceeding should be quite different. A wooden plug or clothes-pin, for example, or, still better, one of glass (Fig. 28), one-half to three-fourths inch in diameter, with one or more circular depressions, is to be introduced into the rectum as a central point of resistance, and given in charge of an assistant. The loop, now made to embrace the entire mass, is to be very moderately tightened at first, and, by an amount of heat barely sufficient to bring this comparatively short length of wire to a cherry red, the operation is to be very slowly proceeded with until the glass or wooden core, as the case may be, has been reached. In the hands of the writer such an operation has usually occupied from twelve to fifteen minutes.

Perineal, rectal, and vaginal fistulæ, when blind or incomplete, may be treated *first* by passing a director through the canal to its bottom and incising with a cautery knife; or, *second*, in case the terminus of the channel should be near the surface, the director may be pushed through, a platinum wire passed, and grasped at either end by the forceps electrode shown in Figs. 3 and 4. By a see-saw movement the fistula can be laid

open. The lining membrane of the fistulous tract should then be cauterized in its entire length and the wound packed. The slough will become loosened in three or four days, when the part should be irrigated and otherwise treated in the usual manner; but there will be no necessity for further packing, as in cases operated on in the ordinary way.

In complete prolapse of the uterus and the vaginal walls of an aggravated type, and for the relief of which plastic operations are useless and mechanical supports out of the question, amputation of the cervix pretty high up, with or without lines or points of cauterization anteriorly and posteriorly, has been a common and successful practice with the writer for many years. In such cases, after removal of the cervix, a firmly-rolled tampon, one and a half inches in diameter and about three inches long, saturated with a mixture composed of tannin, ℥ij; acetic acid, ʒvj; carbolic acid, ʒij; and glycerin, ℥iv, should be applied, and secured in position by a T-bandage. This should be allowed to remain for forty-eight hours, when it is to be removed by a to-and-fro rolling motion, the parts properly irrigated, and a fresh one introduced. This should be repeated every second day for at least two weeks or longer, and, until cicatrization is complete, the patient should not be allowed to assume the erect position. At the end of a month it will usually be found that the uterus shows no disposition to become prolapsed, but, on the contrary, will be firmly fixed in an elevated position.

FIG. 29.

In hypertrophic elongation of the cervix and in chronic hyperplastic enlargement of the portio of inflammatory origin this treatment has also been universally followed by the happiest results.

Kolpocystotomy, for drainage in otherwise incurable cystitis, is an operation which, if performed by cautery instead of knife or scissors, will insure the patient against hæmorrhage and sepsis, and render any subsequent interference, as regards keeping the wound open, entirely uncalled for. Besides, by the use of the vesico-vaginal fixation forceps (Fig. 18), an oblique incision—so likely to follow this operation in the hands of the most expert surgeon—will be impossible. The direct communication between the bladder and the vagina will remain open until the condition of the patient warrants its closure in the ordinary manner.

In performing this operation the patient should be placed in the dorsal position, the pelvis being elevated as in lithotomy. The round, vesical staff of the fixation forceps should be passed through the urethra into the bladder, and, simultaneously, the fenestrated blade carried along the vaginal wall in a direct line with the urethra up to within a short distance—say, one-fourth of an inch—of the fornix. The instrument,

being now closed and securely locked by the ratchet-spring, may be assigned to an assistant, or supported and steadied by the left hand of the operator. In this manner the normal relative position of the vaginal, vesical, and intermediate tissues is maintained, and the risk of an indirect or valvate incision avoided, while the open slit in the lower blade furnishes an accurate and unvarying guide for the cautery knife (Fig. 15). This latter—the blade of which, it will be observed, is bent at nearly a right angle with the handle—is now to be placed in the slit, the battery circuit closed, and the tissues cut through by a few up-and-down strokes until the little platinum blade is found to be in contact with the bottom of the groove in the vesical staff for its entire length, which, in the instrument here shown, is about one inch. The operation is now to be completed by passing the heated knife a few times over the edges of the wound, so as to effect a more thorough cauterization. On releasing and withdrawing the forceps the wound will now be found to represent a long, narrow fenestrum, as if a corresponding piece of the septum had been punched out, while the mucous membrane immediately surrounding the aperture and elsewhere will show no injury from accidental or excessive cauterization, and, it is needless to add, none from heat radiation. At the expiration of from four to six weeks the opening will generally be found to have shortened about one-half, yet leaving ample space for the outflow of urine, and, as a rule, no further contraction follows.

TREATMENT OF STRICTURES BY ELECTROLYSIS; HYPERTROPHY OF THE PROSTATE.

By ROBERT NEWMAN, M.D.,

NEW YORK.

STRICTURES.

It is a well-established fact that strictures in different parts of the body have not only been treated but cured by electrolysis. If such strictures are organic, well defined, local, and not dependent on constitutional causes, electrolysis will cure, if used and handled according to natural laws. The experience of the last twenty years and a record of thousands of cases reported by reliable gentlemen from all over the world have proven this beyond any peradventure.

The Theory of Electrolysis.

The treatment of stricture depends, among other factors, chiefly upon the action of the electricity as a "galvano-chemical absorption." This absorption is the process or act of being made passively to disappear in some other substance, through molecular or other visible means, as the absorption of light, heat, electricity, etc. Electrolysis is the decomposition of a compound body by electricity,—a chemical decomposition. The body to be decomposed must possess certain elements to be an electrolyte, and, as a compound body, must contain water and a salt. A simple element cannot be further subdivided, and, therefore, cannot be an electrolyte. Tissues of the human body have all the properties of an electrolyte, and therefore electrolysis can be applied there, and electrolysis as a chemical action is an undisputed fact.

Nicholson and Carlisle discovered this process of electrical decomposition in 1800, and successfully electrolyzed water into oxygen and hydrogen; therefore the theory is not new, and the explanation can be found in any text-book on elementary physics and chemistry. In combination with this chemical action is the cataphoric, which by some authors is considered an important factor in electrolysis. The explanation lies in the direction of the current interpolar, between the elements from zinc to carbon, or the current from electro-negative to the electro-positive. In the external current between anode and cathode the direction of the current is opposite, and the particles of the fluid gather at the eloctro-negative pole, which is the cathode. The galvanic current only produces the desired result.

The art of applying electrolysis successfully consists in (1) using the correct strength of the electric current; (2) applying the respective

poles in the right place; (3) selecting the size, shape, and material of the electrode; (4) regulating the duration and intervals of *séances*. Electrolysis applied with a mild current will cause absorption only,—a galvanic chemical absorption; while a strong current will burn, cauterize, and even destroy tissues. The operator must know what effect he wishes to produce, and graduate the strength of his current accordingly. The management of the operation must be such that every possible mishap is anticipated and prevented. Always test the battery and ascertain if it is in working-order.

ACTION OF POLES—TESTS FOR THE IDENTITY OF EACH POLE.

We have five principal tests:—

1. *Water Test.*—The simplest and best method is to immerse two electrodes (in the form of platinum needles) in water, and it will be seen that the hydrogen at the negative pole shows itself in distinct bubbles, like pearls, around and above the needle, sparkling almost like carbonic acid in an effervescent.

2. *Meat Test.*—The poles of the battery, in the shape of two needles (platinum are best), are inserted in a piece of fresh raw meat. After electrolytic action has been allowed to take place for a while, the difference in pole action can readily be seen. The positive pole almost destroys it; at the negative pole the color is nearly white, and bubbles of hydrogen appear. In electrolysis the action of the poles is very different, each having its own function. The positive pole attracts the acids and the oxygen from the tissues and coagulates blood. The negative pole attracts the alkalies, hydrogen, and the base of the salt, dissolves blood (but forms a plug from froth of the hydrogen), coagulates albumen, and causes absorption. The positive pole acts like an acid and burns like fire, which is not only exceedingly painful, but may leave a hard, resilient cicatrix. The negative pole acts more like a caustic alkali, which should not hurt so severely during the application, and leaves, if carried to excess, a cicatrix which is soft and not retractile. Thus it is evident that, for the immediate destruction of tumors and for the treatment of strictures, the negative pole should be selected. Electrolysis requires the presence of water, and that is present in every tissue of the human body. It is vitally important to distinguish the poles, and, as we cannot trust to the marks of the instrument-maker, we must always ascertain which is the positive and which the negative pole. The positive pole is noiseless, the litmus-paper applied to it shows an acid reaction, and the needle adheres firmly to its surroundings in the meat; the needle of the negative pole sticks loosely in the meat, can easily be removed, and during electrolysis a hissing sound proceeds from it. A piece of fresh meat still contains water enough to be an electrolyte, while the living body, in which the circulation is active, is better; a dried-up piece of meat is not an electrolyte. The author has made prac-

tical experiments on dogs, on pieces of meat, and pathological specimens, particularly with carcinoma. From among them the following are mentioned: (*a*) Into a piece of fresh raw pork two large platinum needles were inserted, at a distance of three inches apart. The current of 35 cells from a galvanic battery was allowed to pass for fifteen minutes, after which the meat between and around the needles was thoroughly changed into a soft pulp. A weaker current caused changes proportionately; the current of 5 cells produced distinct effects in five seconds, 20 cells in one second. (*b*) Into a piece of meat, containing a bone in its centre, the needles were inserted at a distance of two and a half inches from each other. One large platinum needle was then connected with the positive pole, while with the negative pole two small steel needles were connected. These needles were inserted close to the bone, and one directly into the bone-cells. The galvanic current of 35 cells in fifteen minutes produced changes in the entire tissues, so that the bone around one negative needle was entirely destroyed.

3. *Decomposition of a Salt.*—If, for instance, a solution of iodide of potassium be subjected to electrolysis, one equivalent of hydrate of potassium is liberated at the negative pole, showing that the potassium liberated from combination with the iodine has combined with some of the surrounding water. This can be illustrated by simply holding both poles in the solution while the galvanic battery is in action. The following experiment, however, is more strikingly demonstrative, and is believed to be original with the author. Two small glass vials are filled with a solution of iodide of potassium. For the bottoms of the vials a piece of a pig's bladder is substituted; the necks are then stopped by a cork, through which runs a platinum wire, one end of which is immersed in the solution and the other attached to a pole of the galvanic battery. Both vials, so closed, are now placed in a dish of water; they are six inches distant from each other. There is no communication between them except the water, and so long as the battery is at zero there is no change in the solution, which is transparent and undisturbed; as soon as the battery begins to act the change is visible. Begin with only 6 cells, and you will notice almost immediately, in the vial connected with the positive pole, that in the clear solution streaks of yellow appear, and in about five minutes the vial will contain only a dark-yellow fluid, which is the iodine set free at this pole. At the negative pole the contents of the vial remain clear, only bubbles of froth welling up. This is the hydrogen set free from the water. The result of this electrolysis is iodine, oxygen, and hydriodic acid at the positive pole, while at the negative pole we find hydrogen and potassium. If this same experiment is tried with a faradic battery, as has been often verified, no change whatever takes place in the solution. This is another proof that the action of the galvanic current is widely different from that of the faradic, and that for electrolysis a galvanic current only can be used.

4. *Tests by Galvanoscope (or Milliampèremeter).*—If the two electrodes are brought in contact with each other, the needle will deflect toward the positive pole.

5. *Stammer's polarity distinguisher* is a simple and practical test. It is constructed on the principle discovered by Oersted, that the magnetic needle tends to assume a position at right angles to the direction of the electric current. This little instrument shows the positive pole by the appearance of the red color in either fenestrum, as soon as the poles are held in contact with the instrument.

Size and Material of Electrodes.—The size of the electrodes will concentrate or diminish the force of the electricity accordingly; therefore, an electrode of large size is indicated if the respective pole is used merely to close the circuit, etc. The material of the working electrodes may be metal, such as brass, copper, or silver. This is the negative pole; the bulb is egg- or acorn- shaped. The material of the positive pole, used here to close the circuit, is of brass or carbon covered with sponge or absorbent cotton.

Measurement of Electricity.—At the present stage of progress it is imperative to measure currents used for electrolysis. The milliampèremeter must be used.

Stricture of the Male Urethra.

Definition.—Stricture is a pathological condition of the urethra, structural change of the tissues narrowing permanently the calibre of the urethral canal. This is a progressive change. Text-books describe different kinds and forms of strictures, which have no significance for our purpose. The so-called "spasmodic" stricture is here excluded because: 1. It is a misnomer, as a spasm can cause only a temporary obstruction, not a stricture; therefore it is unscientific and misleading. 2. The galvanic current never cures spasmodic action; on the contrary, it will aggravate and make the obstruction worse. It shows ignorance when some medical men insinuate that strictures reported cured by electrolysis were only spasmodic strictures, but it is a fact that spasm of the bladder and urethra will yield to the faradic current. "The spasmodic stricture" should be expunged from the nomenclature of strictures. Therefore in this work the consideration will be restricted to *the permanent or organic stricture* which results from urethral inflammation by a fibro-plastic deposit of its products, thereby changing first the mucous membrane, next the submucous and cellular tissues, and becoming even calcareous in some cases. This inflammation may be simple, or a cicatricial contraction following the healing of an ulcer.

Etiology.—Anything which may create an inflammation of the urethra is a cause of stricture. Dr. Sturgis,[1] among many others, says that no operation on the urethra, not even the simple introduction of the

[1] Medical Record, New York, February 6, 1892, p. 159.

sound, is entirely devoid of danger. Experience has shown this to be very true, and, therefore, all operative procedures unskillfully executed may lead finally to a stricture, as well as accidental traumatism by external violence. The most frequent causes, however, are the sequels of gonorrhœa, or any urethritis which takes a chronic character or has been treated by too strong injections. The different forms strictures may assume are immaterial, as all organic strictures are amenable to electrolysis.

Symptomatology.—The stream of urine becomes smaller, has less force, and is in some way distorted; urine may scald and cause an uneasiness; gleety discharges are often present, also dull aching in perineum or loins; micturition is more frequent, with symptoms of vesical catarrh. The urine is alkaline, and by degrees loaded with ropy mucus, pus, and even blood, often very offensive; many reflex disturbances can often be directly traced to the existence of a stricture.

Diagnosis.—The presence of a stricture is suggested by these symptoms, but can only be located and apprehended by careful examinations with suitable instruments. The differential diagnosis is nevertheless important, and the following maladies have particularly to be considered and excluded: granular urethritis, chancroids, syphilis, gouty concretions, spasm, prostatitis, catarrh, neuralgia, calculus, tumors, abscesses, hæmorrhoids, and other rectal diseases. Twenty-five per cent. of cases which have been sent to the author by good practitioners for treatment as strictures proved, on examination, to be other diseases, which seems to show that the diagnosis is not as easy as may appear. For instance, a small stream does not always indicate a stricture, particularly if it appears suddenly and is only temporary.

Examination of the stricture is made (1) by instrumental manipulation and the digital touch, (2) by exact measurement, and (3) by ocular inspection.

1. The *exploring instruments* transmit to the operator certain sensations, and experience soon enables him to classify them, and as a result of practice he becomes an expert in their use. Sounds and steel bulbous bougies are generally used. The best instrument is the whalebone bougie à boule, which has a small, olive-shaped head and a slender neck, which adds to its flexibility. Such an exploring instrument gives, from its peculiar shape, a delicacy of touch not to be obtained by any other known bougie. In the normal state of the urethra the bougie glides with comparative ease over its moist mucous lining. The skilled touch will readily detect a stricture, its comparative and relative severity, its location and size, and even the slightest encroachment on the normal standard and calibre. The instant the bougie enters the stricture a peculiar feeling is manifest to the *fingers* of the operator; its penetration is announced with a great degree of certainty; there is a peculiar grasp, "a taking hold," which is distinctly felt on entering or on withdrawing the bougie.

2. *Measurement.*—The location, length, and size of the strictures can be well ascertained and measured by the use of the bougie à boule. However, for this purpose instruments of precision are in vogue, by which all information is gained exactly in a single examination. The most popular of these instruments is Otis's urethrometer. More recently Dr. R. W. Stewart[1] has constructed an instrument, the urethrograph, which gives an exact drawing of the urethral canal on paper like the sphygmograph at each examination. This invention promises to be an improvement on all former systems. The author measures the strictures with a sound or bougie à boule in the following manner: An instrument is introduced as large as the meatus will admit; by this manœuvre we ascertain, at the beginning of our manipulation, the normal calibre of the urethra. The sound is then guided gently forward until we reach the stricture; that being accomplished, we carefully note in inches, by actual measurement, the distance the first stricture is met with from the meatus. Next we ascertain how large a sound the stricture will allow to pass; at the same time an attempt is made to ascertain the length of the stricture. Having discovered the available sound, the exploration is continued until the whole of the stricture has been explored. If any more strictures are discovered during the investigation, they are measured in the same manner as the first, a note of their topography is made and carefully recorded, because in all future operations perfect knowledge of the localities of the impediments is of extreme importance for their proper treatment.

3. *Ocular inspection* by the endoscope or urethroscope will reveal important facts, such as form and color, character, or any complication by which the case may be surrounded. The form of a stricture is not of necessity always annular. The contraction may vary, and assume many different forms. Thus, they may be irregular slits of different sizes, and in all directions; oval, round, square, triangular, and serrated; in fact, of infinite variety. A fact of vast importance, and an extremely valuable factor in the diagnosis, is the following: When the sound or endoscopic tube is withdrawn from the urethra after an exploration, if the stricture is sensibly indurated, the canal closes immediately behind the instrument with great abruptness as it is withdrawn,—a circumstance which is in striking contrast with the gradual closing observed on the withdrawal of the instrument from a healthy urethra. The author has used a modified Desormeauz endoscope for over twenty-five years, as a valuable auxiliary in the treatment of stricture, and only recently added to his armamentarium urethroscopes with electric light. The endoscope or urethroscope will aid materially to make the differential diagnosis of stricture, ulcers, granular urethritis simple congestion, etc.

Treatments of stricture comprise dilatation, divulsion, internal urethrotomy, perineal section, and electrolysis. The latter only can claim

[1] New York Medical Journal, April 12, 1890, page 396.

our attention in these pages. Reliance on medicine is deceptive and absolutely useless in the treatment of stricture in this or in any other part of the body.

History and Armamentarium.

The history of electrolysis in the treatment of urethral strictures is brief. It is freely admitted that the use of electricity in its diversified forms, with the aid of all kinds of instruments, for the cure of stricture of the urethra, was attempted long ago; but the electrolysis under consideration, and its availability to cure stricture, hereafter to be more fully described, are of quite recent date. The first experiments were made by Crussel and Wertheimer, in 1847. The pioneers of the method were Mallez and Tripier;[1] next comes Althaus,[2] Willebrand, Ciniselli, Scoutetten, Bautisto Campos,[3] Dutrieux,[4] and Brenner. Dr. Carl Weiss, of Buffalo, followed Ciniselli's method in a stricture case, in April, 1868, with instruments made by himself. Dr. T. F. Frank,[5] of Titusville, now in Pittsburgh, published two successful cases in 1874, operated on the same principles adopted by the author. Dr. D. Prince, of Jacksonville, Ill., first operated on April 9, 1873, and deserves great credit for his contribution to the practical science in electricity.[6] The author commenced his researches with electrolysis in the treatment of urethral strictures in 1867, and soon established his own method, with new instruments, which in due time were improved. His first paper on the subject was published in the *Medical Record*, New York, July 15, 1872. A more elaborate report,[7] with successful cases, was made at a meeting of the Ulster County Medical Society and at the New York State Medical Society in 1874. This method has been practiced with success by many physicians for the last twenty years and more, and is known as Newman's method, and thus kindly acknowledged by authors and the medical press.

DIFFERENCE BETWEEN THE PRESENT AND THE OLD METHOD OF ELECTROLYSIS.

It will be noticed that the present method, as practiced for the past twenty-two years, differs in many respects from the methods used between the years 1847 and 1870, which is best illustrated in the following comparative table:—

[1] Mallez et Tripier: "Traitement des retrecissements uretraux par la galvano-caustique chimique negative Compte Rendu de l'Acad. des Sciences" (Bulletin Thérapeutique, Mai 30, Med. 58). De la guerison durable de retrecissements de l'urethre par la galvano-caustique chimique. London Lancet, October, 1871.

[2] Althaus in Goerschens Deutsche Klinik, No. 34–36: Heilung der Harnroehren-Stricturen durch die Electrolyse.

[3] Bautisto Campos: De la galvano-caustique chimique, comme moyen du traitement des retrecissements d'urethre. Paris, 1871.

[4] Dutrieux: "De la galvano-caustique chimique dans le traitement des retrecissements organiques de l'urethre" (Press. Méd. Belge., No. 25, 1872).

[5] "Multiple Strictures of the Urethra by Electrolysis," by T. F. Frank, M.D. (New York Medical Record, February, 1874).

[6] Transactions Illinois State Medical Society for 1873. Report by David Prince, M.D., of Jacksonville, Ill.

[7] Transactions of New York State Medical Society, 1874, and Archives for Electrology and Neurology, May, 1874.

Old Method.	Newman's Method.
1. Currents.	
Strong currents, which acted as a cautery, destroyed tissue, and formed a cicatrization.	Weak currents, which absorb by a chemical decomposition, without causing cauterization or cicatrices.
2. Interval between Séances.	
Short intervals, causing new inflammations, *coupe à coupe.*	Long intervals, preventing inflammation and allowing restitution.
3. Selection of Battery.	
Batteries without a fixed potential, large cells, large elements, strong acid fluid, causing cauterization. N. B.—Some operators, however, have used smaller elements.	Improved batteries, with a current of moderate intensity, but a fixed potential, on which depends the results; too high a potential is injurious; too low a potential is ineffective.
4. Electrodes.	
Uncertain copper wires covered by an elastic catheter, uncertain in action.	An established electrode; firm, well polished, with an egg-shaped bulb; a fixed, short curve, well insulated, except at the ends.
5. Tunneled Electrodes.	
No tunneled electrode. No filiform guides. False passages possible.	The electrode-sound tunneled, in order to combine the electrolysis with the passage on a guide, to be used in almost impassable strictures, making false passages an impossibility.
6. The Combination Electrode.	
Formerly, in some cases, the dilated bladder was not relieved, and remained unable to empty the urine voluntarily.	An emergency instrument, adapted on modern principles, combining the electrode with a tunneled sound and a catheter, in order at the same time, with one introduction, to relieve retention, to absorb and dilate the stricture, and guide the instrument through the right channel.
7. Poles.	
	Use of negative pole and no catheterism between and after *séances.*

A graphic description of the old method is given by Dittel, in his work on strictures, p. 173, in which he distinctly says that he used the positive pole (copper) to the stricture, and the negative (zinc) externally on the limbs; that he destroyed the stricture in one sitting by cauterization. It is no wonder that such a method failed and was condemned by him! French operators of the old method called it a "galvano-caustique," which also proves that they intended to cauterize with strong electric currents. It is unfortunate that even nowadays many are so impressed with the old method that they do not take the trouble to read and perceive the difference between the new method of chemical absorp-

tion and the old of "cauterization." Such mistaken ideas are in part the reason why some make objections to a method they do not understand.

The principles of the author's method were recognized and practiced simultaneously with him by Dr. W. F. Hutchinson, of Providence, who has kindly acknowledged it in his work.[1] Others followed soon after, until the method is now an acknowledged practice all over the world. Among the first gentlemen who met successes with this method of electrolysis were Drs. John Butler,[2] Neftel, H. Myntor, of Buffalo; the late Dr. Benson, of Hoboken; A. S. Wolf, of Plattsburgh; A. T. Douglas, of Rondout, now at New London; Dr. Smith, of Rondout. Later, eminent names can be added to this list; among them are: J. M. Glass, D. O. Farrand, J. B. Green, G. C. H. Meier, F. F. Dickman, R. J. Nunn, F. F. Sanders, J. Craft, A. S. Wolff (Jr.), W. C. Wile, Edw. J. Smith, R. W. St. Clair, J. H. Kellogg, G. W. D. Patterson, T. H. Burchard, L. Wolff, J. J. Berry, W. T. Belfield, George E. Pitzer, D. A. Bryce, G. W. Overall, George H. Rohé, Earl, M. S. Tremain, A. A. Shuford, T. C. McCoy, A. P. Sampson, J. D. L. Davis, Hunne, E. S. Stephens, Booth, H. Graff, W. H. Walling, C. P. Thayer, Sutcliffe, Reynolds, Biedler, P. S. Hayes, George H. Simmons, Robert T. Morris, S. T. Anderson, John Fearn, Charles Dake, in the United States; next comes Canada, with Drs. C. R. Dickson, J. J. Cassidy, A. Lapthorn Smith, and eminent surgeons in Great Britain; among them are particularly W. E. Steavenson, W. Bruce Clarke, Edwin Morton, J. T. Hayes, F. Swinford Edwards, and others. Dr. Semeleder, in Mexico; Dr. Leon Danion, in Paris; Dr. H. Park, in Shanghai.

Linear electrolysis in stricture is practiced by Dr. J. A. Fort, who read a paper on this subject at a meeting of the Academy of Medicine, in Paris, on April 14, 1889. He prefers linear electrolytic instruments to urethrotomy.[3] Not having had any personal knowledge of his method of procedure and its results, no further description of it can be made.

INSTRUMENTS.

A complete armamentarium for the treatment of urethral strictures by electrolysis consists of the following instruments, which are made by the Waite & Bartlett Manufacturing Company, George Tiemann & Co., Henry E. Stammers, of New York, and others: A galvanic battery, with conducting cords, one or two handles; electrodes, best of carbon and covered; two or three binding-screws (Fig. 2); one milliampèremeter, filiform guides (Fig. 6), bougies à boule, four sets Newman's electrodes. A good rheostat may be added, which is very convenient, but not absolutely necessary.

[1] Practical Electro-Therapeutics, by William F. Hutchinson, M.D., p. 219. Philadelphia, 1888.

[2] American Journal of Electrology and Neurology, October, 1879.

[3] New York Medical Record, June 15, 1889. J. A. Fort: L'electrolyse lineaire observation Rev. chir. d. mal. d. voies urin, pp. 385–390. Paris, 1891.

The Galvanic Battery.—Any good galvanic battery answers the purpose if the current is steady, without giving shocks by interruptions. A large surface of battery will cauterize with more intensity than any other known caustic, and by using the necessary amount of electric current thus generated the sphere of action is enlarged, and too much inflammation of the surrounding healthy tissues may supervene, thus aggravating the disease. No action should ever destroy healthy tissue, and the concentration of the electric current should be strictly confined to the diseased locality. The battery works to advantage when (1) the intensity of the current can be augmented gradually cell by cell, without any interruption of the current, so that the patient will hardly perceive the increase of intensity; (2) the quantity of electricity is reduced to a point sufficient to produce the most intense action on a very limited space

An acid battery of about 20 cells, with elements of carbon and zinc, will do best for the beginner, if portability and cheapness is desired. Otherwise a good stationary cabinet battery is recommended as a convenience, and an ornament to the office; while a cabinet can be used cell by cell to increase the current gradually, just like a small battery, it will be found that a rheostat is a great convenience; some use for this purpose the Massey current-controller, made by Fleming in Philadelphia.

With the battery are needed cords of copper wire,—not tinsel, which are poor conductors. The positive electrode is best of large carbon, covered with sponge or absorbent cotton. Two or three binding-screws are needed for the connection of the cord with the metal electrode (Fig. 1).

A milliampèremeter to measure the current correctly is, nowadays, an absolute necessity. Some cost only ten dollars, while a fine instrument is expensive; however, a good meter can be bought for twenty-five dollars to thirty-five dollars

The bougie à boule (Fig. 5) is the best exploring instrument. This instrument is made of whalebone, has a small, olive-shaped head and slender neck, which adds to its flexibility. It is used to explore the urethra and find the number, nature, and size of the strictures,—the real topography.

Filiform guides (Fig. 6) are used to prevent false passages; the tunneled electrodes run over these guides with perfect safety.

Newman's urethral electrodes consist of four separate sets, as follow:—

1. The egg-shaped set, Fig. 1. The regular electrodes for all ordinary cases have a short curve, an egg-shaped metallic bulb at the working end, while at the upper end there is a round-wire rod for the binding-screw of the negative pole of the battery; the only points not insulated and acting as conductors are these extremities. The rest of the electrode must be well insulated, smooth, and without inequalities; a coni-

cal bulb is objectionable, as we depend on the electrolytic power of absorption, not on force. The length of the bulb is proportioned to the size of the electrode; thus, for No. 11 French it is three-sixteenths

FIG. 1.—THE EGG-SHAPED ELECTRODE.

inch, while for No. 21 it is three-eighths inch. The set consists of Nos. 11, 14, 17, 18, 20, 21, 23, 25, 28, and 30 of the French scale.

2. The acorn set, Fig. 2. These are for use in the first six inches of the urethra, in certain cases, and consist of Nos. 15, 17, 20, 22, 25, and 27, French. They are without a curve, short, and the bulb is acorn-shaped. Sometimes it is desirable to gain ground by entering the contraction first with the point of the electrode, in order to follow more easily with the larger part of the acorn; then this form will do good

FIG. 2.—ACORN-SHAPED ELECTRODE.

work. The action of the electrolysis depends on the largest diameter of the bulb in these cases, and does most service on the withdrawal of the electrode, when the operator feels best how much work should be done. It is also used when the stricture is near the meatus. It can be ordered in any size.

3. The tunneled electrode, Fig. 3. These are in Nos. 9, 11, 14, 17, 20, and 21, French. They are very important for bad, tortuous strictures, and are to be used only by the expert operator. The curve is shorter,

FIG. 3.—THE TUNNELED ELECTRODE.

and the egg-shaped bulb tunneled, so that it may be introduced easier over a filiform guide (Fig. 6). They are on the principle of the tunneled sound invented by Dr. J. W. S. Goulay, and were devised by the author so that electrolysis and tunneled sound could be used simultaneously. Where the stricture was impassable with ordinary instruments this was used successfully, and passed through the stricture without the possibility of making false passages.

4. The combination electrode, Fig. 4. This is a tunneled electrode for extreme cases. Where a very tight stricture is complicated with retention of urine, the indications are to remove the obstruction and draw off the water with one instrument, as the parts are too sensitive to tolerate the introduction of two instruments in succession. Also, the patient may be benefited by washing out the bladder, all of which can be done with *one* introduction of the instrument. The beginner may

Fig. 4.—The Combination Electrode, Combining Tunneled Electrode and Catheter.

buy just such instruments and sizes as he needs, and add to them as necessity requires, while the busy specialist may want more sizes than specified above.

The electrode-sound (Fig. 1) is the most important part of the instruments, and the greatest care is needed to have it manufactured perfect. Sounds for the perfect exploration of the urethra must be either thoroughly flexible or stiff and unyielding. To the first class belong Nelaton's and Jaques's, and they adapt themselves to the curves

Fig. 5.—Bougie à Boule.

and inequalities of the urethra, but are not applicable for the author's method. The type of the second class of explorers is the steel sound. The operator has it in his power to guide the sound where he pleases; it will not diverge from the course it is directed in; it is firm, never yielding. If the sound makes a false passage the operator is responsible for it. The curve is not so material, but a short curve is preferable, because the operator can guide with his hand and adapt thereby the instrument to the curve of the urethra.

Fig. 6.—Filiform Guide.

Since this method has become popular, some instrument-makers have sold an inferior and cheap article by the thousand. Some have even manufactured, at random, instruments which they sell as Newman's electrodes. With such defective instruments no one can perform the operation correctly. For such, among many other, reasons it is a wonder that more failures have not been reported. Electrodes in which the different sizes of metal bulbs are screwed to one common stem or

handle are always objectionable and dangerous, and should never be manufactured. When the handle and bulb do not fit each other the bulb may be lost in the bladder, and the instrument may carry infection.

Modus Operandi.

The diagnosis having been made, the stricture examined and measured with the bougie à boule (as explained on pages 5 and 6), the history taken, the topography of the urethra well ascertained, and a plan made for the treatment and operation, a full knowledge is attained of what is intended to be accomplished. It is not advisable to operate on the same day; it is better to have one day intervene between preliminary examination and the operation. Genito-urinary surgery is generally applied too severely, and often causes new inflammation instead of allaying it. It is also well to try the patient's susceptibility to the galvanic current, and assure him that he has nothing to fear from a weak current of a galvanic battery, as most people are not familiar with other than shocks. Much is gained if the patient comes to the operation fresh in mind and body, without any nervous depression.

The posture which the patient should assume during the operation is a matter of slight importance; according to his convenience he may stand, sit, or lie on his back, with his shoulders elevated and his knees drawn up. Anæsthetics are not used, for no pain should be caused, and the patient should be conscious, so that he can express his sensations. In exceptional cases of great nervous irritability an injection may be used of cocaine,—a 2- or 4-per-cent. solution. All other preparations must have been made before operating. The galvanic battery must have been previously tested in all its connections, ascertaining without a doubt that the poles have been marked correctly by the manufacturer. The negative metal electrode must be warmed, lubricated with glycerin, and the other end connected by a binding-screw with the cord of the negative pole of the battery. With modern appliances the milliampère-meter and the rheostat must be well connected between the battery and the patient. It is of the greatest importance to fulfill all these details deliberately and carefully, with scrupulous minuteness, in order to secure success.

For ordinary strictures the rule is: to select an electrode which is three numbers larger than the size of the stricture, French scale. For very resilient strictures it may be necessary to take an electrode one or two numbers larger. However, there are exceptions governed by indications. When all preliminary arrangements have been made, the electrode is selected and lubricated, then introduced into the urethra till the bulb is arrested by the stricture. It is also well if on the stem of the electrode a mark has been made, to indicate the distance of the stricture from the meatus; thereby to make certain when the bulb end has reached the beginning of the stricture, according to measurements previously

made. A sponge-electrode, wet with hot or salt water, and connected with the positive pole of the battery, is to be held firmly against the patient's skin, either in the palm of the hand or pressed against the abdomen, the thigh, or some other part, to complete the circuit. At this stage of the procedure it is well to observe that the positive pole touches only the cuticle of the patient, and not any metal. Rings or other jewelry will burn, and must not come into the circuit. While both poles are held in this manner, the current should be increased from zero very slowly and gradually, until the patient feels a warm and slightly-pricking sensation. This increase is made slowly, by one cell at a time, or gradually by the rheostat. At the same time the current is measured by the milliampèremeter: as a rule the current ought not to be stronger than 5 milliampères, and in many cases 3 or 4 will suffice.

The operator must keep the bougie steady against the stricture, and he will soon find that absorption is taking place, that the stricture yields, enlarges, and the instrument slowly advances and passes the obstruction. At times it will fairly jump through the stricture. If there are more strictures than one, the bougie should be guided in the same way until it enters the bladder. Then the electrode is to be withdrawn slowly, and each stricture well worked out, until the first stricture is re-passed, when the current is again to be reduced slowly, cell by cell, to zero; and then and not till then is the electrode to be removed. During the whole operation the electrode must be held loosely and gently in its place against the obstruction, all pressure or force being avoided. The bougie will take care of itself, doing its work by the electrolytic action of the current. It is best to guide the electrode with only the thumb and first finger; sometimes the second finger may be added; all the fingers or the whole hand should never be used. Gentleness must be exercised to the greatest degree, as the use of any force would prevent the action of the electrolysis and only act as any ordinary dilatation. A *séance* may last from five to twenty minutes, and if the electrode has not passed the stricture in that time it is often better to discontinue than to unduly tax the patient, or cause any irritation. The operator must now see that the battery is disconnected and the electrode well cleansed. No other instrument should be introduced until the next *séance*, which can be in from one to two weeks, with an electrode two or three numbers larger than the previous one.

Recapitulation.—As a safe guide for the treatment of electrolysis in stricture of the urethra:—

1. Any good galvanic battery will do which has small elements and is steady in its action; the 20-cell battery with zinc and carbon elements is an excellent instrument, and sufficient for the beginner.

2. The fluid for the battery ought not to be used too strong.

3. Auxiliary instruments are important to the expert, but not necessary for the beginner. However, a milliampèremeter to measure the current is now imperative, and a good rheostat desirable.

4. For the positive pole a carbon electrode is used, covered with sponge, moistened with hot water, and held firmly against the cutaneous surface of the patient's hand, thigh, or abdomen.

5. For the absorption of the stricture the negative pole must be used.

6. Electrode bougies are firm sounds, insulated with a mass of hard-baked rubber. The extremity is a bulb, which is the acting part in contact with the stricture. Four varieties are now in use.

7. The curve of the electrode should be short; large curves are mistakes.

8. The plates must be immersed in the fluid before the electrodes are placed on the patient, and raised again after the electrodes have been removed, if a portable battery is used.

9. All operations must begin and end while the battery is at zero, increasing and decreasing the current slowly and gradually, avoiding any shock to the patient.

10. Before operation, the susceptibility of the patient to the current should be ascertained.

11. The problem is to absorb the stricture, not to cauterize, burn, or destroy tissues.

12. Weak currents, at long intervals.

13. In most cases a current of 6 cells, or from $2\frac{1}{2}$ to 5 milliampères, will do the work, but it must be regulated according to the work to be done.

14. The *séances* should be at intervals, not too frequent in succession, about once a week on an average, and each lasting from five to twenty minutes.

15. The best position for the patient to assume during the operation is that which is most comfortable to himself and to the operator. The author prefers the erect position, although the recumbent or others may be used.

16. Anæsthetics ought to be avoided; the patient is in the best condition when conscious, so that he can tell how he feels. Sometimes, and exceptionally, cocaine may be used.

17. Force should never be used; the bougie must be guided in the most gentle way; the electricity alone must be allowed to do the work. Avoid causing hæmorrhage; if hæmorrhage is present, do not operate.

18. During one *séance* only one electrode should be used. It is never safe to introduce two instruments in succession.

19. All strictures are amenable to treatment by electrolysis.

20. Pain should never be inflicted by the use of electrolysis; therefore it should not be applied when the urethra is in an acute, or even subacute, inflammatory condition.

21. The electrodes should not be greased with substances which are non-conductors and would insulate.

22. For ordinary strictures, the size of the bougie selected should be three numbers (French) larger than the stricture.

The Advantages of Electrolysis.—1. Electrolysis is applicable to all strictures in any part of the urethra. 2. It will pass and enlarge any stricture when other instruments or the skill of surgeons fail, which has often been demonstrated. 3. It causes no pain or inconvenience. 4. It is devoid of danger. 5. It is not followed by hæmorrhage, fever, or any other unpleasant consequence. 6. It relieves at once. 7. The patient is not prevented from attending his daily work or business, and can earn his living while under treatment, without restraint. 8. No relapse takes place, if once cured.

CASES.

There are complications of strictures, different causes, etc., which naturally divide cases in groups. To illustrate more fully such groups and the progress of the treatment, a few cases from the author's note-book are given; most of them have been condensed. They are classified in six groups; in each, one or a few cases are selected:—

Group I. Strictures complicated with urethral granulations or ulcers; use of the endoscope.

Two Strictures; Granular Urethritis; After Three Years No Relapse.

Case 1, No. 104.—E. S., Newark, N. J., aged 25 years. June 26, 1882. Has had gonorrhœa once, three years ago; was cured of it in two months. Noticed a stricture eight months ago. A gleety discharge commenced a few months before the stricture was noticed. At present the stream is small, corkscrewed, and of less power than formerly. Examination with bougie à boule finds the walls of the urethra thickened by hypertrophy; there is no increased sensitiveness. There are two strictures, respectively three and one-half and seven inches from the meatus. The size of the stricture was No. 20 French. June 30th, endoscope shows a large granulation at six and one-fourth inches from the meatus, which spot was touched with a solution of nitrate of silver. A few spots in front are of little importance. July 8th, endoscope. A weaker solution of nitrate of silver was applied to different places, where granulations and indurations were seen. The parts are improved. July 14th, iodoform was applied through endoscope. July 17th, electrolysis; electrode No. 24 French, bulb egg-shaped. Current of 5 milliampères was used for five minutes. The electrode passed the strictures easily. July 27th, endoscope used, and affected parts painted with a brush with a weak solution of nitrate of silver. July 31st, endoscope. Mucous lining red and congested. At six and one-fourth inches a few spots covered with pus are touched with the solution. August 7th, endoscope shows improvement; mucous lining has a more natural color, is not congested, and granulations have disappeared. August 31st, October 10th, and November 14th, electrolysis was used so that No. 27 French passed very easily. Has been under observation three years, and was re-examined August 25, 1885.

Three Strictures; Granular Urethritis; Endoscope; No Relapse After Two Years.

Case 2, No. 129.—H. A. R., aged 52, widower, of New York. When 20 years old had a urethritis, which was not thoroughly cured. Fourteen years ago stricture was noticed and treated by gradual dilatation. At present complains of gleety discharges, soreness in the urethra, and a diminished stream on micturition. Sometimes has spermatorrhœa with stools. Bowels are regular and general condition good. September 19, 1883, examination with the bougie à boule revealed three strictures at one, three, and five inches from the meatus, which

a No. 14 French would pass. The walls of the urethra are thickened and sore on touch. The urethra is very sensitive, and bleeds at a touch. The electrolytic treatment was preceded by mild injections and the use of Mitchell's gelatin urethral bougies, to mitigate the sensitiveness. October 4th, electrolysis with a No. 17 French, egg-shaped bulb. Negative pole to stricture, which passed all strictures in six minutes; 4 milliampères were used, 11 gelatin bougies have been used, and urethra is no longer sensitive. October 10th, electrolysis; No. 20 French passed easily through all the strictures; there is still some soreness. October 20th, electrolysis; No. 21 passed easily. October 29th, endoscope showed an engorged state of the mucous lining throughout the urethra, and granulations. Mitchell's urethral bougies continued. November 5th, endoscope, large tube (easy), showed improvement; granulations treated locally through the endoscope. November 12th, electrolysis with No. 23 French, eleven minutes, 3½ milliampères. December 3d, electrolysis; No. 22 French (easy), eight minutes, 3 milliampères. January 5, 1884, endoscope. Granulations at five and a half inches from the meatus were touched with the solution. January 10th, endoscopic applications were repeated. January 18th, a No. 26 French steel sound passed easily by its own weight, while a current of 2½ milliampères was used, and did not cause the slightest irritation. Two years afterward re-examined; found healthy and without any relapse.

Two Strictures; Ulcer; Electrolysis; Endoscope; No Relapse.

Case 3, No. 180.—W. A. A., aged 26, of New London. Had gonorrhœa three years ago; was treated by too strong injections. Subsequently a stricture was observed and treated by gradual dilatation, then by electrolysis. Next went to Dr. Nelson, of New London, who kindly referred the patient to me. February 24, 1886, examination. Active inflammation has continued, with constant discharge and profuse bleeding on the slightest touch. Painful erections during the night. At one and a half inches was a slight stricture; at four and a half inches a denuded surface, bleeding on touch; and at five inches was another stricture which a No. 20 French would not pass. Weak injections are recommended, and later Mitchell's urethral bougies. During the month of April electrolysis was used, and gradually the calibre of the urethra was enlarged from No. 18 to No. 28 in four *séances.* May 14th, electrolysis with a No. 28, which was almost too large to enter the normal meatus. May 30th, endoscope showed a denuded surface of the mucous lining at four and a half inches, where it was treated by local applications. June, patient well. One year's observation, when his family physician reported him well.

Group II. Strictures complicated with spasm and overdistension of the bladder; prostatitis; retention.

Stricture; Chronic Prostatitis; Cystitis.

Case 4, No. 167.—Dr. G. S. M., aged 49, widower, of Connecticut. For a number of years has suffered from gleet, chronic prostatitis, and cystitis; has had constant irritation and frequent micturition. There is a discharge from the urethra, and for the last eight years has suffered from a stricture. September 17, 1885: The stricture is at two and a half inches from the meatus; the walls of the urethra are indurated, giving a paper-like touch in transmitting the instrument. There are spasms of the bladder and sensitiveness, particularly in the prostatic region. The stricture scarcely admits a No. 20 bougie. Electrolysis with a No. 23 French, acorn-bulb, straight electrode, 3 milliampères, seven minutes, passed the stricture easily. September 27th, electrolysis; No. 25 French, acorn-bulb, straight. This No. 25 is as large as the meatus will admit. The prostate is improved; there is still a little discharge, but the stricture appears to be cured. October 11th and 25th, two more *séances* of electrolysis with Nos. 25 and 26, respectively. The meatus was rather contracted, and had to be stretched to admit the instrument, but it was done with patience, time, and without porotomy. The urethra was capacious and the electrode passed easily. January, 1886: Patient was married last December, and writes that he is perfectly well; prostate is not sensitive, has diminished in size, and there is no trouble since his marriage. Remains well after one year's observation.

Multiple and Impassable Strictures; Prostatitis; Retention; Cure; No Relapse After Seven Years.

Case 5, No. 109.—October, 1885. J. B. S., aged 50; New York City; married. Has been troubled with strictures for six years; has been treated by dilatation; once urethrotomy was performed; all without relief. Has no urethral discharge, but catarrh of the bladder with violent contraction, at times retention. The stream is very small; most of the time the urine dribbles away by overflow of an overdistended bladder. About twenty years ago had a series of attacks of gonorrhœa; after one there was continuous discharge for one year. For the last three weeks his family physician has tried daily to introduce instruments into his urethra, sometimes manipulating for two hours at a time. At last was unable to pass any instrument; offered patient an introduction to a surgeon, saying perineal section was the only means of relief. In this state patient came to me, October 30, 1885, in great agony, with spasm of the bladder and complete retention. On examination with bougie à boule found strictures everywhere throughout the urethra; there were six distinct strictures from one and one-half to eight inches from meatus. Up to five inches a No. 17 French could be introduced, but beyond that the strictures were impassable. Another complication was an enlarged prostate, which pressed, at the neck of the bladder, against the urethra, and prevented the outlet of urine. Electrolysis with the combination electrode-catheter. It was very difficult to introduce any instrument into his irritable urethra, which had been wounded by former injudicious manipulations, and bled at touch. However, I succeeded with a filiform guide, which passed into the bladder. An electrode combination catheter, No. 9 French, tunneled at the end, was then passed over the guide by electrolysis. In twelve minutes the electrode had passed all strictures and entered the bladder. An electric current of 3½ milliampères was used. The guide was withdrawn, as well as the silver stiletto, and a quart of urine drawn off. The spasm of the bladder ceased, and patient felt comfortable at once. November 1st, has micturated in a small stream voluntarily about every three hours; has no pain, soreness is less. November 2d, came to the office nervous and in distress, with spasm of the bladder, fearing another attack of retention. The lower strictures are very tight, and will scarcely admit a filiform guide, which is frequently arrested by the lacunæ. The whole urethra is tender and sore from former injudicious catheterization by the family physician. Electrolysis. Tunneled electrode, No. 11 French, egg-shaped, over a filiform guide, 3 milliampères for fifteen minutes, passed all strictures with difficulty. The treatment by electrolysis was continued for three and one-half months, in which, altogether, nine *séances* were held, and the strictures enlarged from 0 to No. 25 French. It was difficult to manage the case, as the cystitis, enlarged prostate, and mutilated urethra made complications which needed extra care and separate treatment, at the same time. The cicatrix left from the former urethrotomy was more difficult to absorb than any other of the remaining strictures. Hæmorrhagic points in the urethra and the enlarged prostate were successfully treated with the galvano-cautery sound. At that time patient felt so well that he neglected treatment and made a trip south, while he was not considered cured. March, 1887: During a year's absence patient has felt well, without having any inconvenience. He only calls for examination, knowing he was not cured when he left south, and now fearing a relapse. Examination showed that some places in the urethra were sore, excoriated, bleeding on touch, and liable to contract. As patient had not been dismissed as cured, such a condition was expected. For several months he was treated again by electrolysis and an occasional flash of galvano-cautery. Improved so far that soon an electrode, No. 25 French, passed with ease into the bladder. Patient has remained well and has been re-examined several times. The last was seen while writing these lines, in April, 1892.

Three Strictures of Twenty-Six Years' Duration; Retention; Cure; No Relapse.

Case 6, No. 177.—T. D., aged 56; New York; married. January 22, 1886, was sent to me by Dr. C. S. Wood. Has had stricture for twenty-six years. In 1860 a doctor caused him agonizing pains by using a strong injection, which appears to be the cause of his stricture. Has been treated by dilatation off and on. Of late has had spasm of the bladder and

distension, so that he could not void urine voluntarily. The urine dribbled away by overflow and most of the time he had to use a catheter. The stricture closed up more and more till he could neither pass a catheter nor void urine. On examination three strictures were found three and one-half, six and one-half, and seven and one-half inches, respectively, from the meatus. The last two were impassable. With difficulty a filiform guide was introduced. Electrolysis, No. 9 French, tunneled, with combination over guide, passed all strictures. January 27th, electrolysis was repeated with a No. 11 French, tunneled, over a filiform guide (5 milliampères, ten minutes). In the evening came to the house in distress, with retention; was not able to pass water. A siphon arrangement was made and urine drawn off drop by drop. In this manner one and one-half pints of muddy urine evacuated, putrid and loaded with pus. January 28th, at 10 A.M., had not been able to pass water. The bladder had been distended to such an extent that it had lost its contractile power. A small catheter was passed, and, assisting with siphon at intervals, during one and one-half hours fifty-three ounces of urine were emptied from the bladder. This urine was thick, putrid, with solid masses of disorganized, stinkiug pus. At 6 P.M. bladder would not act; flexible catheter would not pass. A small silver catheter was introduced on a guide and twenty-four ounces of water drawn off, which had a better color, was clearer, and contained little pus. January 29th, faradization of bladder to allay vesical spasm, after which he could pass water. While a guide was in the urethra twenty ounces passed. Bladder washed out; the urine is improved. January 30th, micturition voluntarily. February 1st, electrolysis; No. 14 French, egg-shaped, tunneled, over guide, 4 milliampères, seven minutes. February 3d, bladder washed out and dilated. February 5th, electrolysis; No. 17 French, egg-shaped bulb, tunneled, over guide, after which he passed a better stream. February 11th, micturates now voluntarily; says he has not passed so good a stream in twenty-six years. February 13th, electrolysis; No. 18 tunneled electrode passed very tightly. February 17th: Now empties the bladder voluntarily and with ease, and no residue is left. February 27th, electrolysis; No. 20 French, straight, acorn-bulb. March 16th, electrolysis; No. 21 French. May 31st, electrolysis; No. 24 French passed well. The treatment by electrolysis and washing out the bladder was continued in the same manner till July, when a No. 25 French sound passed easily into the bladder and patient felt well, having regained full power of his bladder. He objected to further treatment or a larger calibre of his urethra, as he was perfectly content with his present state of health and comfort. One year after was re-examined; no relapse. November 24, 1889, three years after, re-examined with the same result. 1892, patient is seen frequently; has remained in perfect health, without any relapse for over six years.

GROUP III. Traumatic strictures, some accompanied by perineal fistula.

Traumatic Stricture in the Prostatic Urethra of Nine Years' Standing.

CASE 7, No. 140.—Dr. W. T., aged 39, New York, April 1, 1884, has had urethritis and a stricture of nine years' standing. By an accident a ragged instrument cut the urethra in the prostatic portion, partly in the neck of the bladder. This was not healed and a constant source of annoyance, causing hæmorrhage at intervals, particularly on passing an instrument. Part of this cut has cicatrized and caused the stricture, the other part remaining as a granulating ulcer. Electrolysis was used by an excellent practitioner, who failed because he used too strong a current and handled the instruments carelessly. Examination revealed unevenness caused by the traumatization on the lower side of the urethra, in its depending portion, left side. Electrolysis was used with a No. 25 French, egg-shaped bulb, negative pole against the stricture, 5 milliampères for twelve minutes, with decidedly good result. During six months of very irregular attendance ten *séances* were held with electrolysis. The electrode gradually enlarging until a No. 32 French passed easily into the bladder without causing any pain or hæmorrhage. No. 30 would have been large enough, but No. 32 was used at the special wish of the patient. 1887, the patient has remained well.

Traumatic Stricture; Perineal Fistula.

Case 8, No. 179.—B. U. H., aged 35; New London; married. Had a stricture for last six years, occasioned by an accident to the perineum. A urethral abscess behind the scrotum appeared, which in time broke and established three separate fistulæ, through which matter and urine passed. Had been treated by different physicians. Urethrotomy had been used without benefit. The strictures grew smaller, so that voluntary micturition was difficult and retention prevailed. The bladder was distended and the urine dribbled away from the overflow. The constant dribbling of urine and discharge from fistulous openings made it necessary to wear a urinal. Patient failed in every way, and was not able to attend to any business. Then he applied to Dr. A. W. Nelson, a well-known, conscientious surgeon of New London, who referred him to Dr. A. T. Douglas, of the same place, to be treated by electrolysis. January, 1886: From this time the patient was treated by Dr. Douglas and the author. There were two distinct strictures at three and one-half and six and one-half inches, respectively, from the meatus, one of which was so small that no instrument would pass. The urethra was irritable, the walls indurated, the fistulæ in the perineum running, and the perineum itself changed to an unrecognizable mass of infiltrated tissues. Dr. Douglas succeeded very well with the electrolytic treatment and enlarged the strictures in a few *séances*. February 4th, the author operated, in New London, with electrolysis, in the presence of Drs. Douglas, Nelson, Bramman, and Stanton. The strictures were passed with a No. 25 French, egg-shaped bulb. Soon afterward the patient felt well and passed voluntarily a good stream of urine. February 9th, Dr. Douglas wrote: "H. was here about half an hour ago, and says he has never passed his water so freely as he did Friday and Saturday." Subsequent applications of electrolysis made him a healthy urethra of No. 28 size. The fistulæ all healed spontaneously as soon as the strictures were enlarged. February 18, 1887, a re-examination showed that no contractions had taken place. A No. 28 passes easily into the bladder, and the patient has enjoyed perfect health and attended to his business.

Four Strictures of Eighteen Years' Duration; Traumatism; Cure; No Relapse.

Case 9, No. 183.—H. K., aged 42; married; New York City. Has had strictures for eighteen years, caused by former urethritis and accidents. Has also suffered from cystitis; received a kick in the perineum by accident. Once he used a sound so forcibly that he ruptured the urethra. Has been treated off and on, mostly by gradual dilation, without much benefit. April 9, 1886, examination. Bougie à boule meets slight indurations and thickenings of the walls of the urethra, and is arrested at five and one-half inches. Sound No. 12 will not pass this stricture. A filiform guide passes easily into the bladder, over which a tunneled sound, No. 9, ran tightly by electrolytic action. There were four strictures at four, five and one-quarter, six and one-quarter, and seven and one-quarter inches from the meatus. April 15th, electrolysis; filiform guide, over which a tunneled electrode, No. 11 French, egg-shaped, was used, 4 milliampères for eight minutes. It passed through all strictures; the hard-ring stricture at six and one-half inches was overcome by slow manipulations and lowering the curve of the instrument. Dr. Lawson was present. April 22d, electrolysis with a No. 14 French, egg-shaped bulb, tunneled, over a filiform guide; 7 cells were used with a current of 4 milliampères for fifteen minutes. Progress was very slow, but steady, and the electrode passed all strictures. May 19th, electrolysis over a filiform guide with a tunneled No. 17. Took fifteen minutes to open all strictures. Current 4½ milliampères. May 26th, electrolysis; No. 18 French, egg-shaped bulb; no guide; in ten minutes 3½ milliampères current passed all strictures slowly and steadily. June 2d, electrolysis; a No. 20 French passed easily into the bladder in eight minutes; current, 4 milliampères. June 9th, electrolysis with a No. 23 egg-shaped bulb; eight minutes, 4 milliampères passed. June 17th, electrolysis; No. 25 French, nine minutes, 4 milliampères. June 30th, electrolysis; No. 28 French passed slowly and rather tightly. July 14th, electrolysis with No. 28 French, egg-shaped bulb, passed easily. October 6th, was re-examined with a No. 28 French, and urethra was found well; no trace of strictures found. May, 1888, well. On re-examination with a No. 28 French electrode, found well; without any relapse. 1891,

December 12, Dr. Lawson reports that the patient died about a year ago at Sharon Springs, from rheumatism, with failure of heart, but that the strictures remained cured, without any relapse. The treatment of this case was typical in regard to its regular progress at each *séance*.

GROUP IV. Impassable strictures. This group has, in a measure, been anticipated in former cases, as it is a complication concomitant with other troubles. A stricture is called impassable when the smallest regular instrument cannot be introduced through the obstruction of the urethra. In these cases the urine may dribble away, but a filiform guide can generally be introduced.

Traumatic Strictures of Forty-One Years' Standing; Impassable.

CASE 10, No. 138.—March, 1884, A. N., aged 48 years, New York, has had a stricture for forty-one years, occasioned when a boy 7 years old, by falling from a hay-loft astraddle on an oat-bin. The strictures were multiplied by urethritis contracted in later life. March, 1884, came under the observation of the author. The urethral canal was so small that the bougie à boule or any other regular instrument would not pass farther than two and one-half inches from the meatus. After some manipulations a filiform guide entered. Electrolysis with a No. 9 French, conical end, tunneled electrode was used over the guide. A current of 5 milliampères for nine minutes was successful, and passed two strictures and the spasm into the bladder. There were two strictures at two and one-half and three inches, respectively, from the meatus. After two more successful *séances* of electrolysis a No. 14 French passed the strictures, when the patient disappeared. September 5, 1886, nearly two and one-half years later, the patient re-appears, with the following story: While he was perfectly satisfied with the progress made by electrolysis, he was persuaded to have a cutting operation. He submitted to urethrotomy. Six weeks after a sound, No. 30 French, passed easily, and he was declared cured. One year afterward an eminent surgeon had to make an official report, and he found that the patient had two tight strictures at two and one-half and three inches from the meatus, proving that urethrotomy had been a decided failure, and the gentleman lost his position in consequence. Since then the strictures have contracted more. The patient came to-day frightened and begging for electrolysis again. The strictures were found to be contracted to about No. 18 French, and the cicatrices caused by the after-effects of the cutting so tough that they were calcareous, and yielded very slowly to absorption. The electric *séances* were recommended in intervals, and the calibre of the urethra gradually enlarged to a No. 28 French size. The patient is now well. May, 1887, was re-examined with a No. 28, which proved that no relapse had taken place. March, 1892, has been seen, and remains well.

Impassable Stricture; Retention.

CASE 11, No. 168.—P. E., aged 38; New York City; widower. October 11, 1885, has had gonorrhœa in former years. The stricture was marked two years ago, when the stream became gradually smaller and made micturition very troublesome. At present he cannot pass water at all, and is relieved only by dribbling, from the overflow of a distended bladder. No bougie will pass the urethra, and the patient is in great distress, having positive retention. A filiform guide made its way with the greatest difficulty; there is really no urethra. Electrolysis. Positive electrode was held in the palm of his hand; the negative pole, a tunneled electrode with a conical end, No. 9 French size, was passed over the filiform guide, and advanced very slowly but steadily, and finally passed into the bladder. The urine was drawn off; 4 milliampères were used for six minutes. In this case it was impossible to state the number of strictures, as the whole urethra was a mass of strictures. October 25th, electrolysis. The filiform guide entered after some time spent in manipulations. No. 11 French, tunneled, conical end, was very tight, and advanced very slowly. The worst point of the stricture is at six and one-half inches. Ten minutes were occupied

with a current of 5 milliampères. November 2d, electrolysis ; No. 18 French, egg-shaped bulb, 3½ milliampères for eleven minutes. November 10th, electrolysis ; No. 18 French, egg-shaped, no guide. November 18th, electrolysis ; No. 20 French, egg-shaped, no guide. November 30th, electrolysis ; No. 23 French, egg-shaped, no guide. December 4th, electrolysis ; No. 25 French, egg-shaped, no guide. November, 1886, one year after, was re-examined with a No. 25 sound. 1887, heard from ; is well.

Group V. Strictures which are complicated with constitutional diseases, as gout, rheumatism, pyelitis, syphilis, etc. Typical cases we find in Nos. 114, 126, 154, and 185 of the second hundred cases of urethral stricture treated by electrolysis.[1] It is scarcely necessary to give these cases in detail. The point is to call attention to the fact that such diseases aggravate the strictures to the degree of acute inflammation. These inflammations must be subdued before electrolysis is used. Such intercurrent diseases must be treated according to their nature and indications.

Group VI. Regular cases of stricture, single or multiple. These are typical cases, as they appear most frequently, and appear oftenest before the general practitioner. One case will suffice to show, as a general rule, the treatment :—

Case 12, No. 148.—J. W., aged 32 ; married. New York City, July 28, 1884. Twelve years ago contracted venereal ; had urethritis, chancroids, and bubo ; the latter was lanced. Two years ago had another urethritis, which ran into gleet, and is still present. Every morning the meatus sticks together with a film, which, when broken, lets out two drops, which are almost transparent, white, and sticky. The stream of water has grown smaller, and is now very thin, twisted, and without force. Since last year the testicles are swollen. Examination : Testicles hang down low, simulating a degree of degeneration of tuberculosis. Meatus is small. Bougie à boule meets with indurated walls throughout the urethra ; the touch transmitted by the instrument is like parchment, and in a few spots cartilaginous. The course of the urethra is tortuous. Four strictures are found, in the following places : first stricture is near the meatus ; second stricture is four inches from the meatus ; third stricture is five inches from the meatus ; fourth stricture is six and one-fourth inches from the meatus. August 3d, a filiform guide met with obstacles everywhere, but was finally introduced into the bladder. Electrolysis. Positive sponge-electrode is held by patient and pressed in the palm of his hand. The negative pole is a No. 14 French electrode, egg-shaped bulb, tunneled to run over the guide in the urethra. The current applied was 4 milliampères for five minutes. The electrode passed slowly through all the strictures into the bladder. Patient is weak, run down constitutionally, and nervous. August 4th, feels better ; has voided urine easier. August 10th, electrolysis over guide, with tunneled electrode No. 17 French, egg-shaped bulb ; 4½ milliampères, eleven minutes, passed easily through all strictures. While the instrument was in the bladder, some spasm took place. August 17th, electrolysis ; No. 17 French, egg-shaped, without a guide, advanced easily. August 24th, electrolysis ; No. 20 French passed all strictures ; 5 milliampères, six minutes. August 31st, meatus is very small, so that it will not admit of a larger size than No. 20. September 21st, electrolysis. The meatus is enlarged by an electrical stretcher, which worked so well that a No. 28 could be introduced. September 28th and October 5th, the electrolysis with the meatus-stretcher was repeated. October 12th, he is better in every way ; has no gleety discharge. Bougie cannot detect any stricture. Is well. October, 1885, re-examined with a No. 28. No relapse. Well.

[1] Journal American Medical Association, September 24, 1887.

AUTHOR'S STATISTICS.

Among other reports of successful cases, the author has published 200 cases. The first hundred was a part of a paper delivered before the section in surgery, at the American Medical Association, in Cleveland, in 1883, which was published in two parts,[1] as a part of the manuscript was destroyed by fire in the printing establishment; the second part appeared later.[2] In 1887 appeared the synopsis of the second hundred cases.[3] These cases were selected from consecutive numbers, such as warranted a complete history, being long enough under treatment and observation afterward to afford verification. These patients were dismissed or stopped treatment themselves, when they felt comfortable and well, had a calibre of the urethra which enabled them to void freely a good large stream, and are free to indulge the functions without any fear of a relapse.

In recapitulating these 200 cases the following points will be interesting. The electrolytic treatment enlarged the calibre of the strictures, according to the French scale, as follows:—

Strictures	which	admitted	no	instrument	were	enlarged	from No. 17 to 28,	respectively.
Strictures	which	admitted	a No. 2	instrument	were	enlarged	to No. 23.	
"	"	"	a No. 6	"	"	"	from No. 17 to 28,	respectively.
"	"	"	a No. 7	"	"	"	to No. 23.	
"	"	"	a No. 8	"	"	"	to No. 28.	
"	"	"	a No. 9	"	"	"	from No. 23 to 28,	respectively.
"	"	"	a No. 11	"	"	"	from No. 26 to 28,	"
"	"	"	a No. 12	"	"	"	from No. 24 to 28,	"
"	"	"	a No. 13	"	"	"	from No. 24 to 28,	"
"	"	"	a No. 14	"	"	"	from No. 20 to 30,	"
"	"	"	a No. 15	"	"	"	from No. 22 to 28,	"
"	"	"	a No. 16	"	"	"	from No. 23 to 26,	"
"	"	"	a No. 17	"	"	"	from No. 23 to 28,	"
"	"	"	a No. 18	"	"	"	from No. 25 to 32,	"
"	"	"	a No. 20	"	"	"	from No. 25 to 30,	"
"	"	"	a No. 21	"	"	"	from No. 25 to 32,	"
"	"	"	a No. 23	"	"	"	from No. 26 to 32,	"
"	"	"	a No. 25	"	"	"	from No. 30 to 32,	"

The result of the enlargement of the calibre of the urethra varied according to circumstances, as necessities, wishes of the patients, time allowed for treatment, nature of the stricture, complications, vices or virtues of the patients. But results must be considered very good, even by advocates of other methods, if a calibre of a urethra can be enlarged to a No. 28 French by electrolysis, when at the first visit no instrument would pass, and experts have tried in vain before. In some cases the family physician has tried for weeks, in others celebrated professors were given chances, without being able to pass any instrument; and the disposition of the cases was the advice of perineal section. The undeniable

[1] Journal American Medical Association, April 25, 1885.
[2] New England Medical Monthly, August, 1885.
[3] Journal American Medical Association, September 24, 1887.

fact, often demonstrated and verified by witnesses, is that the power of electrolysis enlarged the calibre when manual force or dilation could not move the instrument.

Duration of Strictures.—The duration of the strictures at the time the patients presented themselves for treatment varied from 1 month to 41 years, and in recapitulating we find 2 cases of 1 month's standing, 2 cases of 3 months, 2 cases of 4 months, 4 cases of 6 months, 1 case of 9 months, 3 cases of 1 year, 10 cases of 2 years, 6 cases of 3 years, 6 cases of 4 years, 11 cases of 5 years, 6 cases of 6 years, 5 cases of 7 years, 4 cases of 8 years, 4 cases of 9 years, 4 cases of 10 years, 2 cases of 11 years, 1 case of 12 years, 2 cases of 13 years, 1 case of 14 years, 2 cases of 15 years, 1 case of 16 years, 2 cases of 18 years, 1 case of 19 years, 7 cases of 20 years, 2 cases of 21 years, 2 cases of 25 years, 2 cases of 26 years, 1 case of 30 years, 4 not known, and, later, strictures have been observed of 50 years' standing.

Percentage of Single and Multiple Strictures.—In the first series of 100 cases we find 42 single and 58 multiple strictures, with a total of 189 strictures. In the second series of 100 cases we have only 21 single and 79 multiple, with a total of 230 strictures. There is a striking difference between the two series, and it seems that the average appearance is more correctly given by the first figures; so we may expect that nearly one-half of the patients presenting themselves have single strictures. The increase of multiple strictures in the report of the last years may arise from the fact that more bad cases were transferred to me. The number of strictures in one individual we find as follows:—

	First 100.	Second 100.	Average in 200.
1. Stricture in	42	21	31½ cases.
2. " "	34	43	38½ "
3. " "	17	26	21½ "
4. " "	5	7	6 "
5. " "	2	1	1½ "
6. " "	0	2	1 "

Location of Strictures.—The location of the strictures was found in all parts of the urethra, from the meatus to more than eight inches from it, as follows:—

Location of Strictures in	First 100.	Second 100.	Average in 200.
At the meatus, or less than 1 inch from meatus	8	9	8½ cases.
At 1 inch, or less than 2 inches from meatus	12	12	12 "
At 2 inches, " 3 " "	31	24	27 "
At 3 " " 4 " "	25	41	33 "
At 4 " " 5 " "	42	30	36 "
At 5 " " 6 " "	37	46	41 "
At 6 " " 7 " "	24	40	32 "
At 7 " " 8 " "	0	20	10 "
At 8 inches or more from meatus	10	8	9 "

Situation.—The greatest number of strictures were from 4 to 6 inches in the first 100 cases; from 5 to 6 inches in the second 100 cases;

or in the first part of the urethra. In the membranous part, 10 per cent. from 100, 20 per cent. second 100; average in 200 cases, 15 per cent. In the prostatic part, 5 per cent., first 100; 8 per cent., second 100; average in 200 cases, $6\frac{1}{2}$ per cent.

This combined statistic of 200 cases confirms the observations made at the report of the first series, that strictures appear in every portion of the urethra, about 10 per cent. in the membranous and about 5 per cent. in the prostatic portion; some of the latter were of traumatic origin. It seems to be a mistake to believe that there are no strictures in the prostatic portion of the urethra, and that the largest number are situated within three inches from the meatus. However, it is true that spasm and prostatic maladies are often mistaken for strictures. The observations of the later years have not changed the foregoing statistics.

Objections Made.—In reality there can be no valid objections to the method of electrolysis in the treatment of urethral strictures, and those which have been raised from time to time come either from men entirely ignorant of the first physical laws of electricity, or from such as have had a personal interest or feeling in the matter. To the latter class in the opposition belong some surgeons of high standing, who are wedded to the knife, have not tested the electrolysis, and hence are opposed to any innovation. Most of such objections are entirely unfounded, based on false theories, or are too trivial and even ludicrous to be considered. Some have even the stamp of misstatements purposely made. One friend objects to the treatment because it does not always cure a prostatitis or any other discharge. Of course, it does not always; and discharges will only be cured if their existence is caused by the stricture; but if there are granulations, or other causes, electrolytic treatment has nothing to do with it. Some are aggrieved to hear that to succeed it is necessary to understand electricity and the handling of the genito-urinary instruments. Now, there is scarcely a profession, business, or even common labor which can be exercised without an apprenticeship, and in any vocation expertness is needed to be successful. The same objection could be raised to any operation, or even to the practice of medicine.

A London surgeon does not like the long intervals between *séances*, without giving any reason for it. If necessary, he may operate at shorter periods. One distinguished friend, who is most persistent in his opposition to this method, argues as follows: Electrolysis is a heat; heat burns; burns make cicatrices; cicatrices make every stricture worse; *ergo*, electrolysis is no good! Now, that gentleman ought to know better, after having read articles on the subject, and heard explanations. It is distinctly advised, always practiced, and insisted upon, to use weak currents of from $2\frac{1}{2}$ to 5 milliampères; so that the electrolysis acts as a chemical decomposition by absorption, which never burns or destroys tissues. If some gentlemen use too strong currents, or the positive instead of the negative pole, they make gross mistakes, must necessarily

fail, destroy tissues, and ruin their patients. If professors and others have made such mistakes and failures it is to be lamented, but does not harm the reputation of a good method, approved by acknowledged successes all over the world, in a very great number of cases. It is more than ludicrous to read the report of a crank, who has the *naïveté* to measure electricity by a thermometer. While using faulty instruments, which cauterize instead of electrolyze, he shows that the current burns, because the thermometer is marked 95° F. Is that man not afraid to burn everything by the touch of his hands, which certainly must have a higher temperature?

Other similar objections are answered by stating that the endoscope has been used in observing strictures for a period of over twenty years; that experiments have been made on dogs, and the assertions proven by vivisections, post-mortems, and, moreover, by a great number of successful cases, many of which have been re-examined after three to eleven years, without a relapse of the cured stricture having been found, and that similar reports and observations have been made by many other surgeons.

Similar objections were raised in London to Drs. Steavenson and Bruce Clarke's paper, read before the Royal Medical and Chirurgical Society, when the report of the author's 100 cases "without relapse" was alluded to. One speaker sarcastically observed: "It is a very remarkable fact about Dr. Newman's cases that they were all successful." The answer to this was brought out by Dr. Steavenson, in an article in the *British Medical Journal*, July 23, 1887, p. 173, as follows: "That critic overlooks the fact that, in the selections of those 100 cases, the first essential point was that they were discharged as cured in order to see whether or not relapse would take place. Those 100 cases were naturally not consecutive cases, but were collected chronologically, and had to meet the following conditions: 1. The patients were to have been under treatment regularly and for a reasonable time. 2. They were to have been discharged as cured, or at least so improved that the patients were content with the result, and did not wish any further treatment or improvement. 3. They were to be cases that were heard of afterward by reliable information, mostly re-examined by the family physician, or by Dr. Newman himself. Some of these patients came repeatedly for such re-examination. 4. That a reasonable time had been allowed between the discharge when cured and the re-examination, which in these cases was, respectively, from three to eleven years. The proof of 'no relapse' was that the same-sized sound was used in the re-examination which passed the last time at the close of the treatment; that is, if the calibre of the urethra had been enlarged to a No. 26 French, the same No. 26 passed again after the period of from three to eleven years. All these facts have been distinctly stated, and those skeptical critics have overlooked the facts, and therefore have been unjust."

Why is it advisable to use gradually larger and larger electrodes? This is a question by a gentleman who wants to prove thereby that the enlargement of the calibre was done by pressure. The answer is, that the electricity can do only a certain work in a certain time, and that it would be impossible to subject the patient to such increased work, and to such prolongated time in one *séance*, without doing great harm. It is considered a good result to enlarge the calibre of the urethra by three

FIG. 7.

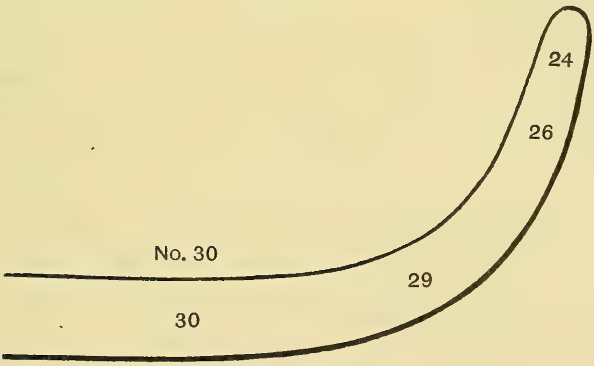

FIG. 8.

FIGS. 7 and 8.—THE ORDINARY STEEL SOUNDS, THE END CONICAL AND OF SMALLER SIZE.

sizes in one *séance*. And when such a three-size-larger sound cannot be pressed through a stricture, but passes by the action of electrolysis, no pressure being used, it is the best proof that the electrolysis did such work, and not dilation. This has been often demonstrated.

Difference in Sizes between Newman's Electrodes and Sounds.—Another objection has been made, that in the reported cases the strictures have not been cured, because the calibre had not been enlarged to No. 40 French, in some cases. The attention is called to the difference of the author's electrodes and the usual instruments. The accompanying diagrams are made from measurement of instruments in actual use.

The first two figures (Nos. 7 and 8) represent the ordinary steel sounds, which are conical at the end, and the number is expressed by the size of the largest part of the stem, making a real difference of from six to eight numbers in different parts of the instrument. The latter two figures (Nos. 9 and 10) represent Newman's electrodes, which have their full size at its bulb-end, as numbered. It will be seen at a glance that in the steel sounds a No. 38 is, at its conical end, only a No. 24; this tapering end making a difference of four and nine numbers, respectively.

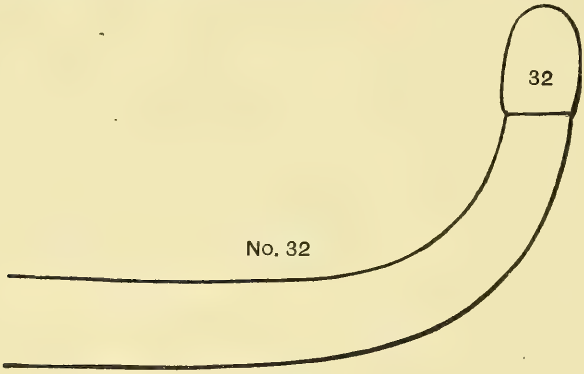

Fig. 9.

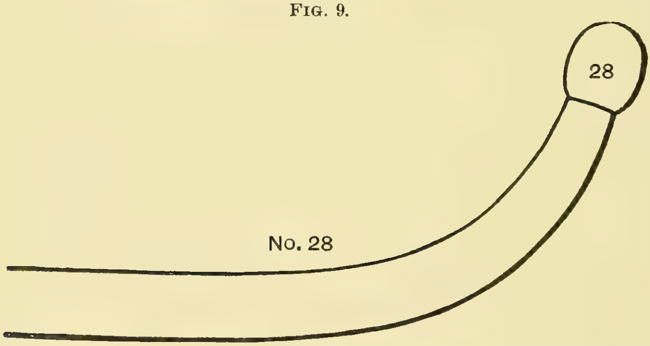

Fig. 10.

Figs. 9 and 10.—Newman's Electrodes, the End having its Full Size, as Marked.

Therefore, the No. 32 French Newman's electrode is, at its end, as large as the No. 40 steel sound. Hence, the diversity of opinion above referred to is in a great measure explained by these diagrams, especially in relation to the treatment by electrolysis. What is understood by a cure of a stricture, and why sometimes it is better to be satisfied with a calibre enlarged to electrode No. 28 or 25, has been stated before.

Failures.—If the rules in the treatment, as just described, are carefully carried out by the operator as well as by his patient, there ought to be no failures, or at least they will be very rare. It is, however, an undeniable fact that failures have been reported, even by excellent medical practitioners. The cause of such failures, in most instances, could be

traced to bad management, in which all rules of physical laws and surgical dexterity were ignored. In brief, the cause of such failures depends on: 1. The operator; his incompetency, carelessness, want of patience, mismanagement of the case, or a wrong diagnosis. 2. Faulty instruments. 3. The patient himself, in not following orders, or being tampered with.

These include almost all causes of failures, some or all of which have been mentioned as above. In individual cases the fault has been shown to friends and correspondents. More details have been given in other papers, as "Ten Years' Experience in the Treatment of Strictures of the Urethra by Electrolysis;"[1] "Is Electrolysis a Failure in the Treatment of Urethral Stricture;"[2] "Success and Failure of Electrolysis in Urethral Strictures;"[3] "A Defense of Electrolysis in Urethral Strictures," and a very good article, is written by Dr. G. C. H. Meier;[4] "Why Electrolytic Treatment of Stricture Does Not Succeed in All Hands."[5] Electrolysis is a chemical and electric action; is sure, and cannot fail; but complications and accidents, some even unavoidable, may cause a failure, as in any other operation.

Relapses.—One of the advantages of this operation is that when a stricture is cured, as a rule, no relapse takes place. Many reports by different operators have confirmed this statement. These statistics have been explained. A few operators, however, have found in their practice that relapses have occurred, and the question naturally arises whether such reports do not contradict the former statement of the writer, that relapses do not take place. There is scarcely a rule without an exception, and there is hardly an operation which may not sometimes fail, from some unforeseen concomitant circumstances. In the operation under consideration relapses are very rare, and, where they occur, may have been induced by the very same causes which have been mentioned under the causes of avoidable failures, heretofore referred to. It is safe to state that relapses will not occur when the patient has been dismissed as cured. The conditions are that the strictures must be treated until they are cured by having assumed healthy tissues, all the fibrinous, cartilaginous, and cicatricial encroachments entirely removed, and the size of the calibre sufficiently enlarged. It is not necessary that the calibre be enlarged to theoretical fancy numbers, and not even to its normal size; but to such a calibre that the patient can comfortably micturate, and that the bladder is not forced to extra exertions and painful contraction, in order to relieve itself of the water, which must be expelled for its comfort and rest. This is generally accomplished after an electrode of No. 25 or 28 French scale has passed easily, but exceptionally some patients may be declared

[1] New York Medical Record, August 12 and 19, 1882.
[2] *Ibid.*, September 25, 1886.
[3] Philadelphia Medical Times, December 15, 1888.
[4] Medical Register, Philadelphia, January 5, 1889.
[5] International Journal of Surgery, October, 1888.

well after the passage of a No. 23, and some other patients need a larger calibre, until they can be dismissed as cured. As many patients absent themselves after an improvement, when they feel comfortable, and without being cured, it is a natural consequence that the stricture will close up again, and such patients return reporting "worse," or go to another practitioner, telling him the electrolytic treatment was followed by a relapse. While such cases have been observed, it cannot be called a relapse in its true meaning.

The success of electrolysis in the treatment of urethral stricture is so well established and proven by (1) reports of thousands of successful cases by different trustworthy writers; (2) patients who have been for many years observed, re-examined, and can bear testimony of permanent results; (3) acknowledgment by the medical press, journals, and modern text-books; (4) documentary evidence.

The follwing quotations may be of interest as a proof of the success. The literature on the subject and hosts of successful operations are mentioned in an editorial of the *New England Medical Monthly*,[1] under the title, "What is the Present Status of Electrolysis in the Treatment of Urethral Stricture?" which holds good to-day. There it is said: "It is undeniable that the method now adopted was first grasped and put forward by Dr. Robert Newman until, by extraordinary success, the most skeptical are convinced." Dr. W. E. Steavenson says also, in his work,[2] page 76: "During the last decade it has been developed and improved by Dr. Robert Newman, of New York, to such an extent that it has now become one of the recognized modes of treatment of stricture." On page 77 he says: "I obtained the assistance of Mr. Bruce Clarke in the autumn of 1888. Since then we have had numerous cases, which have established beyond a doubt that electrolysis is one of the most efficient and satisfactory modes of treating stricture of the urethra." Dr. A. F. Sampson, Galveston, Tex., reported successful cases and read a paper before the Texas State Medical Association, April, 1885. Dr. T. C. McCoy, Fort Worth, Tex., writes that he has treated three hundred cases, sees patients again, and finds they are well without having had any relapse. Mr. W. Bruce Clarke has read several papers before medical societies in London, in which he cites many successful cases, one series embracing fifty cases.

More evidence comes almost daily from honest workers who formerly were skeptics, or failed at first, and at last relate their successes. Among the latter, as an instance worthy of notice, the valuable article of F. Swinford Edwards, F.R.C.S., surgeon to the West London Hospital, and surgeon to the out-patients of St. Peter's Hospital for Fistula, etc.,[3] from which the author takes the liberty to quote: "When, some

[1] New England Medical Monthly, December, 1887.

[2] The Uses of Electrolysis in Surgery, by W. E. Steavenson, M.D., M.R., C.T. London: J. & A. Churchill, 1890.

[3] Medical Press and Circular, April 11, 1888.

two and a half years ago, the treatment of urethral stricture by electrolysis was taken up by my friends, Dr. Steavenson and Mr. Bruce Clarke, who were led to test its merits from the published reports of a brilliant series of cases by Dr. Newman, of New York, I determined to try it here at St. Peter's, and more especially in cases of resilient, or non-dilatable, stricture, which in the usual course would be submitted to some cutting operation, attended possibly by risk of life; at all events, necessitating detention in the hospital for one or more weeks,—a loss of time which is of great moment to many, and most can ill afford. . . . There is yet another reason why I have selected only the severest form of stricture in which to test the capabilities of this method. It is in order, that there should be no room for an objection which I heard raised. . . . In the table of cases before you, most of the strictures were of long duration, and were multiple. Now, these strictures were no myths, nor was their resilient character open to doubt, some of them having been in the hospital under my colleagues, while others had been under the care of well-known hospital surgeons. The number of strictures, their calibre, and distance from the meatus have been noted and the result of treatment given, I trust, with impartiality. . . . The first I treated with the aid of my friend, Dr. Steavenson; and so struck was I with the result obtained, that I hastened to give electrolysis a fair trial at this hospital. The patient had been under me two and a half years previously with three strictures, which, after a month's treatment, I succeeded in dilating to No. 25. In February, 1886, he came to me again for stricture, but on this occasion I was unable to dilate the subpubic one by passing bougies. This, then, I conceived to be a good test case for the new treatment. For the result I have put down 'cured,' as six months afterward, although he had undergone no treatment in the meantime, I found no sign of stricture, after carefully examining his urethra."

Two letters from Dr. Wile, of Danbury, and his patient physician are reported here, by permission:—

DANBURY, CONN., November 24, 1888.

MY DEAR DOCTOR: In reply to your courteous note of November 24th, I will state that I have seen cases successfully treated by you,—cases of stricture of the urethra which I have examined before and after treatment. I know organic stricture existed, and that they were cured. I have already treated about fifty cases myself, and all, except spasmodic stricture and those due to masturbation or of neurotic origin, have been either cured or so much relieved that all the objectionable symptoms have disappeared and the patient passed a full stream with no inconvenience whatever, and gave up the treatment of his own accord. This I consider one of the greatest drawbacks to electrolysis, that the treatment is so painless, and the relief so sudden, the patients consider themselves well before they are: consequently there is re-contraction, and the case is counted against the method by those who oppose it. Last Wednesday evening, before the Danbury Medical Society, I read a paper on this subject, and demonstrated its utility by operating upon a patient of Dr. Brown's, of this city, passing with the galvanic current in fifteen minutes a No. 20 electrode, where three weeks before, when Dr. Brown first brought him to me, we could with the utmost difficulty pass a filiform bougie; thus demonstrating, by test, that in four *séances* I had

dilated painlessly from almost nothing to a No. 20 French. The patient was a hack-driver, and, according to his own history, given that evening before twenty or more physicians, he had never had a moment's pain or inconvenience, and had attended to his duties right straight along. I have on the table before me a letter from an eminent physician of Maryland, who came to me, while in Philadelphia, for a stricture which proved to be two inches and one-quarter long. He is 67 years old, and it took me seven *séances*, with a No. 11 French, tunneled electrode, threaded on a filiform bougie, to get through. This was the largest instrument that could be introduced at the time of my first seeing him. It took him three minutes and a quarter at that time to micturate. In reply to a letter from me he says :—

October 1, 1888.

"Dear Doctor : Your favor of ——— was received, and I was glad to hear from you. I have been thinking of writing to you for several months, but have been so on the go that I neglected it. I have been gone most of the time since early summer, and arrived home a few weeks ago from an extended tour through Canada, the White Mountains, etc. I think (thanks to your skillful treatment) I am perfectly well of the stricture. Have not used the battery for four months ; but pass No. 30 electrode every six weeks, without the slightest trouble, and without meeting with the least resistance anywhere in the urethral canal. If I did not know from previous experience, I could not tell in what part of the canal the stricture had been located. The stream is round and full ; all irritability of the bladder is gone ; and, what is best of all, I have not had an attack of gout since the first *séance*, which is now over fifteen months ; having never had over four months to elapse without an attack, previous to the electrolysis, for the last three years. Of course, I cannot say positively that the removal of the stricture, which was hard and dense, and had existed since 1860, is the reason that I have been exempt from the gout ; but I firmly believe it. My feet are not now tender at all, and I can wear shoes as tight as I could in boyish days. I have not been traveling for my health at all, but for pleasure and the gratification of my better half. I never used more than seven cells ; and, after twice using seven, never went beyond five. The last time I introduced the No. 30 electrode, which was a week ago, nine weeks had elapsed since its previous introduction, owing to being away ; but I did not encounter the slightest trouble, pain, or inconvenience on its introduction, and did it as quickly as you could introduce an ordinary catheter into a perfectly normal urethra. Of course, I mean I did it without using the battery at all. When you consider how dense and hard and long-standing the stricture was (over twenty-six years), and how the smallest electrode could not be passed, and even found it difficult to pass a filiform bougie, I think the results have been simply marvelous. And, no matter what is said or who disputes the efficacy of electrolysis in urethral strictures, I will swear by it every time ; for facts are stubborn things that cannot be ignored, and have been proved beyond the shadow of a doubt, under my own observation, and in my own person. I am satisfied that, to accomplish the best results from electrolysis in urethral stricture, the *séances* ought not to be very close together. I should say two weeks, unless circumstances were such that the patient could not be gotten at at pleasure."

It will be seen that I withhold the gentleman's name, but the case can be vouched for by Professor Shoemaker, of Philadelphia. W. C. Wile, M.D.

The following letter from Dr. J. B. Greene, of Mishawaka, will also prove that after a cure by electrolysis no relapse took place, and that the urethra was restored to a normal state, which was ascertained at the post-mortem : —

Mishawaka, Ind., March 17, 1890.

My Dear Doctor : I write you for the purpose of informing you of the permanency of cure of urethral stricture by electrolysis. In 1884 I treated Mr. Henry C., of this country, for an old or rather a series of old urethral (gonorrhœal) strictures. The first bulb passed was No. 12 French ; when I discharged him (within the next three months) a No. 19 French steel would easily enter the bladder. I heard no more of any urethral difficulty, and attended him during his last illness, in October and November, 1889. He died in November. After

death, in the presence of Dr. R. T. Van Pelt, of this place, and Dr. C. M. Butterworth and A. L. Wagner, of South Bend, Ind., I made a post-mortem. I particularly called the attention of the gentlemen to the condition the urethra had been in, and they, one and all, after thorough and careful examination, declared the urethra perfectly healthy, and the prostate normal, neither indurated nor hypertrophied, which is remarkable in a man 72 years of age. I know there was a prostatic enlargement when I first examined the case, and I think its normal appearance, post-mortem, was the result of the cure of the stricture. Case 2 was one of a traumatic stricture, the result of a kick in the perineum in 1885. When he applied for treatment, he had suffered for a number of years; he passed urine drop by drop with great difficulty. I inserted a filiform bougie, found a stricture of fully two inches in deep perineum. Succeeded in introducing a No. 6 French, which I made myself, insulating the staff with gum-shellac, from that to 8, 10, 12, and run to 18, with intervals of not less than ten days nor over fourteen between *séances*. I saw no more of the case, after the No. 18 introduction, until last month, nearly five years. I examined him thoroughly, and found no sign of the stricture. He takes a No. 18 French steel readily, and of its own weight. His name is H. A. P., Jackson, Mich. I am curing more cases of chronic gonorrhœa with your prostatic cautery-sound than I ever expected to cure by any means. Again thanking you for your valuable investigation, and hoping, etc., etc.

Very truly yours, J. B. Greene.

Dr. W. F. Hutchinson, of Providence, an acknowledged authority in electricity, says in his excellent work, recently published ("Practical Electro-Therapeutics," p. 219), as follows: "Looking over my list of operations, several hundred in number, I see but two that need special description. These two are for urethral stricture and uterine fibroids. The galvanic operation for the former was devised at about the same time by Dr. Robert Newman and myself, and fully tabulated by Dr. Newman, who has had large dispensary experience with it, as well as a great number of private cases. Dr. Newman deserves a pioneer's laurels in this new path."

Dr. W. E. Steavenson, whose authority as an electrician in London is acknowledged, and whose successes are recorded, also writes to the author in private letters, from which is cited the following:—

"39 Welbeck Street, London, December 6, 1886.

"I can quite indorse what you say about the causes of failure in the electrolysis of stricture. I do not believe it can ever become the universal method of treatment by all practitioners, although no doubt the best; but medical men will never take the necessary trouble; they have not the patience and perseverance, and the operation, without care, may fail from so many different causes. I have never had the least hesitation in referring to you as an authority on the permanency of the cure, for every one of your countrymen (and that is not a few), who have visited my electrical department at St. Bartholomew's Hospital, have assured me that any statement made by you may be implicitly relied upon."

"September 30, 1888.

"Dear Dr. Newman: I am glad to see, by the (September 8) number of the *American Medical Journal*, that you have answered the very weak criticism of Dr. Thomas. I had almost thought of writing an answer myself, but it is much better answered by you. I wrote a long paper on the treatment of stricture of the urethra by electrolysis, in the July number of the *Provincial Medical Journal*, published at Leicester, in this country. In referring to my cases of stricture of the urethra, I find that a large number of patients cease to attend, and are satisfied when the calibre of their urethra is enlarged to No. 22 French, which corresponds to about No. 12 on the English scale. It is impossible to keep either private or hospital patients on as long as one would wish. I remain," etc.

The following remarks of Dr. C. S. Wood, at the meeting of the Northwestern Medical and Surgical Society of New York, April 18, 1888, are taken from the *Medical Record*, June 16, 1888, p. 674: "Dr. Wood was pleased with the favorable consideration given to this subject, after the years of criticism and vituperation which had been heaped upon it, especially in this city. Regarding the question of cauterization, he recalled a former meeting held in his own house, where Dr. Newman had demonstrated the effect of the current, using cartilage covered with mucous membrane. The cartilage had been dissolved and returned to its original elements, while the mucous membrane had been uninjured. He recalled a case which he had referred to Dr. Newman for treatment. The patient was 50 years of age, the bladder emptied by drops, and a filiform bougie was entered with difficulty. The patient had suffered with chills, and had been disqualified for business for several months. After eight weeks' treatment he was entirely cured, and has no difficulty since. The speaker had recently referred the question of recurrence to Drs. Bangs and McBurney, at the St. Luke's Hospital. He had asked whether, after division of stricture at one point, there was permanent cure. They had replied that the sound must be passed occasionally for a year, or even during life in some cases. The permanency of the cure by electrolysis was thus in its favor. Electrolysis destroyed the whole of the ring, while internal urethrotomy destroyed it in but one place."

Dr. J. J. Berry, Portsmouth, N. H., has recently reported more successful cases,[1] and, in a letter to the author, concluded:—

"September 13, 1888.

"If the process of electrolysis is effective in even one case, it occurs, to a greater or less extent, in all: and I then attribute any partial failure in one of those cases to lack of technical skill and experience rather than to the method itself. Wishing you continued successes, I am," etc.

The following extract is from a letter of Dr. R. W. St. Clair, Brooklyn, N. Y.:—

"April 10, 1888.

"DEAR DOCTOR: For the last five years I have been a follower of yours. I was one of the first to believe in and take up your treatment of urethral stricture. I have read everything from your treatment of urethral stricture. I have read everything from your pen with the greatest care, and have treated some one hundred patients, for stricture, by electrolysis. I have had the best results; and whenever I write up a case I always give the credit where it belongs, and that is to Robert Newman," etc.

The eminent leader of the great Sanitarium of Battle Creek, Mich., Dr. J. H. Kellog, writes, in a letter:—

"February 9, 1888.

"DEAR DOCTOR: Please accept thanks for your two valuable papers, just received. I have made use of your method in the treatment of stricture with good results, and am anxious to try the cautery method in treating a large prostate," etc.

These quotations are given to show how universally the method of electrolysis in the treatment of urethral strictures has been adopted and

[1] Southern Medical Record, p. 250.

successfully practiced. There is more on file,—an abundance. There are also witnesses and documentary evidences for everything stated herein.

Strictures of the Rectum.

Dr. George H. Rohé, of Baltimore, says[1]: "The treatment of stricture of the rectum by gradual dilatation or linear proctotomy is notoriously unsatisfactory. All surgeons admit the inefficiency of the first and the danger of the second. In electrolysis we have a safe and apparently efficient method of treatment."

Dr. W. E. Steavenson writes[2]: "Strictures of the rectum can, like all other strictures, be treated by electricity. In the majority of cases there is no recontraction or return of the stricture, but, if due to cancer, a fresh growth of diseased tissue is very likely to take place, necessitating a recourse to the treatment. Successive applications of electricity are far better than the *dernier ressort* of colotomy, and may keep the intestines patent as long as the disease allows the patient to live."

Indorsed by other equally eminent authorities, thea uthor joins emphatically in recommending the adoption of electrolysis as THE treatment for rectal strictures. This opinion is further strengthened by experience and successes, some of which have been published.[3] The author has treated successfully strictures of the rectum by electrolysis since March, 1871,[4] and, as the literature on this subject records no cases prior to 1871, he believes he is the originator of this method. The plan of treatment followed out in those cases is almost identical with the method of treating urethral strictures by electrolysis. The principle is well explained in a valuable article by Dr. George H. Rohé, of Baltimore, —"The Electrolytic Decomposition of Organic Tissues."[5]

Instruments.—The armamentarium consists of a good galvanic battery with conducting cords, handles with sponge-electrodes, a few binding-screws, a set of rectal electrodes of different size and shape, and a milliampèremeter to measure the electric current. The electrodes have at one end a metal bulb, copper or brass, silver- or nickle- plated. The form is flat or egg-shaped; they are made in sets of different sizes; the length is from one-fourth inch to one and one-fourth inches, and the circumference from one and one-eighth to three inches. The stem of the electrode, except at the extremities, is insulated with hard or soft rubber; some are flexible, others stiff. If larger sizes are needed, a metallic bulb is used, similar in shape and size to vaginal electrodes,

[1] Atlanta Medical and Surgical Journal, July, 1888, p. 297.

[2] The Uses of Electrolysis in Surgery, by W. E. Steavenson, M.D., etc. London: J. & A. Churchill, 1890.

[3] Journal American Medical Association, May 17, 1890.

[4] Specimen presented to New York Pathological Society, April 10, 1872. New York Medical Record, vii, 1872, p. 208.

[5] New York Medical Journal, December 1, 1888.

which are from three to five inches in circumference. Recently, Waite & Bartlett have made for the author an electrode for examination and treatment which is superior to all former instruments. It consists of a bulb on a spiral stem, insulated with a rubber covering. The instrument will accommodate itself to the flexures and easily enter the colon, thereby increasing the field of observation. Undue force is prevented; neither can the tube double up or turn on itself. If made long enough, it will enter into the transverse colon.

Modus Operandi.—The patient may be placed in the Sims position, on the left side; but in the majority of cases the lithotomy position, on the back, is preferable, because in the examination and operation the anatomical relations of rectum and colon with the sigmoid flexure can be better appreciated. The galvanic battery is brought into action with the switch at zero. The sponge-electrode, wet with warm water, and connected with the positive pole of the battery, is placed firmly in the palm of the patient's hand, but in some cases may be pressed on the abdomen or thigh. The negative metal-electrode is lubricated with glycerin and inserted per anum to the seat of the stricture, and only then the electric current is slowly increased from zero, cell by cell, until the desired strength is reached, which is ascertained mainly by the sensation of the patient.

The strength of the current allowable varies from 5 to 15 or even 20 milliampères, according to the seat of stricture, the nature of the neoplasm, the size of the electrode, and the susceptibility of the patient; the rule always being not to use a strong current if a weak one will accomplish the object. The *séance* may last from five to fifteen minutes. No force should be used; the electrode should be kept steadily against the stricture, and only guided; the electrolysis does the work of enlarging the calibre as the instrument passes the obstruction. At the end of the *séance* the current is reduced slowly to zero, and not until then is the electrode to be removed.

It will be perceived that the occasionally stronger current in this operation is the only difference from the treatment of urethral strictures. *Séances* may be repeated in one or two weeks. According to circumstances and complications of the disease, some modifications of the treatment may be called for, one of which is the use of needles in the mass of the stricture, instead of the metal bulb, at the negative pole. The smaller electrodes are very flexible and long, the object being that undue force is impossible while being used. Some operators use stronger currents, particularly if anæsthetics are used. Dr. Earle has used 50 to 100 milliampères. The author has witnessed an operation by Dr. W. F. Hutchinson when 39 milliampères were well tolerated. If neoplasms are present, or carcinoma is suspected, stronger currents are indicated; they may be practiced under an anæsthetic with needles, in the same manner as in the treatment of tumors.

TABULAR STATEMENT OF REPORTED CASES. THE AUTHOR'S TWELVE CASES.

Cases.	Sex.	Age.	Strictures. No.	Strictures. Location.	Strictures. Duration	Cause and Complication.	Result of Previous Treatment.	Result of Electrolysis.	Remarks and Sequels.
1. M. V.	F.	24	1	$2\frac{1}{2}$ inches.	6 mos.	Venereal; five fistulæ.	Dilatation; no success.	Cure.	Post-mortem specimen showed no relapse.
2. Mrs. D.	F.	62	1	4 inches.	2 yrs.	Constipation; atony.	Medical; no success.	Cure.	No relapse in ten years.
3. Mrs. P.	F.	30	1	$1\frac{1}{2}$ inches.	5 yrs.	Syphilis; pelvic cellulitis.	Dilatation; proctotomy, etc.; relapse.	Cure.	Remained well, as long as heard from, for ten years.
4. M. B.	F.	38	1	$2\frac{1}{2}$ inches.	2 yrs.	Hæmorrhoids; constipation.	Operation; relapse.	Cure.	Not heard from.
5. Mrs. M. A. C.	F.	36	4	2, 3, $5\frac{1}{4}$, and 10 inches.	5 yrs.	Syphilis; malaria, tuberculosis.	Dilatation; relapse.	Improved.	Not heard from.
6. L. S.	F.	35	3	$1\frac{3}{4}$, 3, and 5 inches.	5 yrs.	Constipation.	Proctotomy repeated; relapse.	Improved.	Proctotomy; afterward used rectal bougies; relapse; died Oct., 1888.
7. R. B. A.	F.	43	2	5 and 10 inches.	3 yrs.	Membranous enteritis.	. . . .	Cure.	Heard from; no relapse for four years.
8. G. E. W.	M.	23	1	$3\frac{1}{2}$ inches.	1 year.	Dysentery; suspected malignancy.	Failure.	Cure.	Well after six years; reexamined in Apr., 1892.
9. J. M. R.	F.	46	1	$1\frac{1}{2}$ inches.	10 yrs.	Hæmorrhoids; fissure.	Proctotomy; operation; relapse.	Cure.	Well; no relapse in five years.
10. E. M. B.	F.	44	2	3 and 5 inches.	20 yrs.	Hæmorrhoids; constipation.	Operation; relapse.	Cure.	Well; no relapse in one year.
11. H. K.	M.	26	1	4 inches.	1 year.	Dysentery; proctitis, prolapsus, constipation.	Medical.	Cure.	Well; no relapse in four years.
12. B. L.	F.	30	1	$2\frac{1}{2}$ inches.	3 yrs.	Tumor of uncertain nature.	. . . .	Cure.	Well; no relapse in four years.
13. S. T.[1]	F.	39	1	2 inches.	4 yrs.	Polypoid growths.	Dilatation failed.	Cure.	Well after two years.
14. H. W.[2]	F.	30	1	1 inch.	7 yrs.	Specific lesions; neoplasm.	Dilatation; proctotomy; failure.	Much improved.	Well after one year.

[1] Case reported by Dr. S. Benton, London.

[2] Case reported by Dr. S. T. Earle, Jr., Baltimore.

Other cases have been reported, with more or less successful results, by W. T. Whitmore and H. E. Steavenson, of London, and J. B. Greene, of Mishawaka, Ind. J. A. Fort, of Paris, reports cases treated by linear electrolysis. The limited space does not permit a history of all the cases in detail, but some explanation of the foregoing statistics will prove interesting:—

CASE 1.—Stricture of the rectum; rectal fistulæ; failure by gradual dilatation; success by electrolysis; cure proven by post-mortem specimen and microscopical examination.

The report of this case is complete, and shows the perfect success of electrolysis. It was a very bad case, the patient's loose habits and neglect counteracting all benefits of treatment. No fair play was given to the method, as after the first operation any further necessary treatment was not permitted. The case was complicated by five fistulæ. The patient died, nearly seven months after the operation, from acute peritonitis after a debauch, and not from the disease under consideration. The specimen showed, under all these adverse circumstances, an improvement, which cannot be called anything but a decided success. Dr. Terry kindly assisted at the post-mortem, and immediately after made a microscopical examination of the rectum. He reports that the microscope showed no heterologous tissue, and nothing strictly neoplastic. The specimen was presented to the Pathological Society on the same evening, April 10, 1872, and showed that the stricture had not troubled the patient; that it had not grown worse since the operation, but, on the contrary, had improved.

CASE 2.—Mrs. D., aged 62 years. May, 1875, stricture was cured and no relapse occurred in ten years. Dr. Frank, of Pittsburgh, saw this case. No other cause for this stricture could be found than the atony of old age, in consequence of constipation and impacted fæces, which made a pouch below, and, by constantly pulling downward, elongated and, lastly, paralyzed some fibres. Above this atonic part the contraction acted stronger and stronger, overpowering the parts below; spasmodic action followed; the mucous membrane became divided in folds, which again contracted until a firm stricture, almost a closure, was created.

CASE 3.—Mrs. P., aged 30 years. Stricture syphilitic, complicated with pelvic cellulitis; was sent to the author by Dr. Bosworth. Patient had no relapse, after the electrolytic treatment, in ten years, after which time Dr. Bosworth wrote that "the patient cannot be found."

CASE 4.—Surgical operation had failed; electrolysis a success. Patient went home well, and has not been heard from. Dr. G. C. H. Meier assisted in this case.

CASE 5.—Four rectal strictures; recto-vaginal fistula, syphilis, tuberculosis; improved by electrolysis. Mrs. M. A. C., aged 36, was a patient of Dr. C. Lockwood, who was frequently present during treatment. Dr. C. W. King sometimes assisted. This was a very aggravated case, which in the table is rated as improved only.

CASE 6.—Three strictures. Repeated operative procedures had failed. Electrolysis improved slowly, but without a final success, after which was operated again with the knife; had to use rectal bougies; a relapse occurred; reported carcinomatous, and patient died in October, 1888. Mrs. L. S., aged 35, was seen first in 1882. Dr. Meier and others assisted in the treatment. The case was so severe that sometimes a needle was used. One record is as follows: "January 24, electrolysis. Dr. Meier administered ether. Positive large sponge-electrode was held on abdomen; a negative pole, a large platinum needle spear-shaped

at the end, was thrust into the lower margin of the annular ring of the strictures. A strong current of about 25 milliampères was used, and the needle held in a direction so that it absorbed the tissue from the inside toward the free passage of the rectum, thereby dividing that part of the strictures by electrolysis. After that, electrolysis was applied with a metal-bulb electrode two and one-half inches in circumference, which passed easily through the strictures. Then a larger metal bulb three inches in circumference could be introduced and passed up its whole length. The strictures are about one inch long. After the operation the patient walked home, a distance of about three miles." "August, 1884: The case at present is unsatisfactory. While a year ago the improvement was steady and promised to result in a brilliant success, to-day a relapse has taken place. The tight stricture is found in a different situation, but, nevertheless, we have a stricture in which parts of the rectum are involved. Patient is in indigent circumstances; has to bring up four small children, and has neither time, room, nor means to take care of herself." Therefore, the question came up if it would be better to have an operation performed in a hospital. Dr. J. D. Bryant kindly offered to take the patient in his ward of Bellevue Hospital. He proposed to operate by exsection of the stricture, then pulling down the healthy rectal tissue and stitching it to the lower part of the anus. This plan could not be carried out, because it was found at the operation that the thickened tissue of the stricture extended too high up; therefore the stricture was divided by the knife and excised as much as possible. The operation was performed in a masterly manner, and has benefited the patient very much. Patient has had to use a rectal bougie off and on, and thereby kept herself going since the operation. Saw her four years after the operation; she was still using the rectal bougie faithfully. Later, heard from her husband that a relapse had taken place, complicated with a tumor, and that finally she died, in October, 1888. The tumor was said to be carcinomatous.

CASE 7.—Stricture cured by electrolysis. Her family physician reported, after four years, that she had kept well without having had a relapse. Mrs. R. B. A., aged 43, of Pennsylvania. Six years ago had prolapsus uteri. Stricture commenced three and one-half years ago, after a membranous enteritis. After a short time of treatment, went home well.

The following case is of particular interest, and more extensive notes are given here because (1) it describes the progress of the treatment; (2) many prominent surgeons have examined the case, and have acknowledged that a cure had been effected by electrolysis; and (3) the result proved to be even better than formerly claimed:—

CASE 8.—Stricture three and one-half inches from anus; failure of cutting operation; carcinoma suspected; cure by electrolysis; no relapse after six years; re-examined April, 1892. G. E. W., aged 23 years; medical student. September 8, 1886, presented himself saying that he had a stricture of the rectum, which formed one year ago, after a severe attack of dysentery. He had consulted many prominent professors, a cutting operation had been performed, and he was no better. On examination the stricture was found to be three and one-half inches from the anus; the index finger just reached the beginning of the stricture, which was annular, defined just like a new formation in a large cavity of the rectum; the walls very indurated, not yielding or stretching. On further exploration with a bougie, the stricture was found to be one inch long and the parts above seemed healthy. Small papillæ on the under surface of the stricture could be felt distinctly. Electrolysis was applied, with a very weak current for five minutes. Positive sponge-electrode was applied over sacral region; the negative direct to the stricture by a flat metal, one inch long. September 19th, electrolysis was repeated in the same manner as before for twelve minutes; the negative bulb was one inch long and one and one-half inches in circumference. September 26th, electrolysis. Negative pole had at its end a round metal bulb two inches in circumference, which passed the stricture easily; current of 5 milliampères was used for fifteen minutes. The bulb around which the electricity worked was one and one-half inches long, the other part of the electrode being insulated. The current was weak, did not hurt; there was only a warm sensation in rectum, a little stronger than at the positive pole. Patient had no inconvenience during or after the operation. October 3d, electrolysis. Nega-

tive pole, larger than used before, was a round metal ball two and one-fourth inches in circumference and one-half inch long; was held in stricture for fourteen minutes. Very little improvement; papillomata were growing larger. October 8th, electrolysis. As negative a large, round, metal bulb three and one-half inches in circumference passed all inside and up the stricture; current of 5 milliampères for sixteen minutes. There was an improvement. Drs. Kelsey and Sands individually examined the patient, and also pronounced an improvement. October 15th, electrolysis, in the same manner as last time; the electrode passed through easily, and three inches above the stricture. Current was stronger, full of power of 12 cells. The stricture was unquestionably better, but the papillomatous growth had increased. October 22d, electrolysis. The electrode passed still easier, but papillomata were worse. October 29th, electrolysis as before for fifteen minutes, with a strong current. November 7th, 14th, and 22d, three applications of electrolysis. In the last two applications, as a negative pole, a metallic dilator was used, with two blades, which were extended by degrees to four and one-fourth inches in circumference. The current was 5 milliampères for twelve minutes. November 30th, the twelfth application of electrolysis was given; there was then a decided improvement; stricture was softer, more dilatable, while the margins were distinct, and indurated tissues surrounded it. December 22d, electrolysis. As a negative a new electrode dilator was used, which had been made for the case; it was extended to five inches in circumference; current of 14 cells for fourteen minutes, measured 6½ milliampères. January 9, 1887, electrolysis with the new dilator electrode extended to four and one-half inches. Stricture was much improved, but the growth appeared to increase. January 16th, electrolysis repeated as before, but circuit of electricity applied with a larger resistance; postive electrode held in hand; new dilator as negative in rectum was an improvement; 7 milliampères for fifteen minutes. From January 24th till March 9th six more *séances* were held, in the same manner as before. There certainly was improvement of the stricture; it was softer in every respect, the indurations were softer, and an instrument of four and one-half inches in circumference could pass the stricture, and while *in situ* could be expanded to five inches.

Patient could not stay longer in New York, and went south to his home. He has written several times informing me of the state of his health. His last letter will best explain the history of the case, and it is copied here verbatim, as also parts of several other letters pertaining to the case:—

April 10, 1889.

Dr. Robert Newman:

My Dear Doctor: I will recite for you with pleasure, as nearly as I can now recall them, the principal points in the history of my case. I am 25 years old, and my family history is good in every respect, my father being a German and my mother an American woman. My own health has in the main always been good. I have suffered ill health at times from rather severe attacks of intermittent fever, and went through the usual diseases of childhood. Have also suffered much, from 1882 to 1885, from nervous exhaustion, cerebral hyperæmia, and well-defined symptoms of lithæmia, none of which were treated properly until lately. I have never had any venereal disease, and, beyond suffering much at different times from constipation, I have never had cause to suspect that my rectum was not in a thoroughly healthy condition.

On September 14, 1885, I arrived in New York, with the intention of taking the winter course of lectures at the University Medical College. Just after my arrival in the city I had an attack of dysenteric diarrhœa to commence. No especial cause was assigned for the trouble by either Drs. Weisse or Thomson (both of whom prescribed for me at different times), and it was evidently not considered of a serious nature, as I was able to attend lectures about half of the time during the two months I remained in the city. For two or three days immediately preceding my arrival in New York I had rather overtaxed my physical powers in sight-seeing in Washington, and just before my arrival in the city I ate two oranges which were rather old and unsound. An hour afterward, having reached the college building and started out to look for a boarding-house, feeling much exhausted I

dropped into a First Avenue bar and took a glass of beer, which proved not to be good, and an hour afterward I had to look for a water-closet. At no time was blood noticed in the passages, and at the commencement of the attack there was not much tenesmus, but some pain in the perineum (which I had noticed a day or two just before arriving in New York, and was attributed to the much walking I had done in Washington).

About November 1st I was attacked with articular rheumatism, and left for home a few days afterward. The trip home aggravated both the diarrhœa and the rheumatism, and for some days after my arrival home the rectum was so inflamed and sensitive that a cocoa-butter suppository with opium could not be retained. The salicylate treatment was used for the rheumatism and the subnitrate of bismuth and pepsin discarded, and opium in one form or another used instead for the diarrhœa. I recovered from the rheumatism after the usual six weeks, and the diarrhœa (or dysentery?) was controlled soon afterward.

While my dysentery was worst, my physician here endeavored to make an examination of the rectum by introducing a duck-bill speculum, and, although nothing was discovered at this examination, it is entirely probable that this lack of discovery was owing to the examination having been unskillfully made, as, after straining much at stool two hours after the examination, I removed with my fingers, from within the grasp of the sphincter ani, an annular, pendulous growth as large as an ordinary lead-pencil. It was about one and one-half inches long, hollow (or annular), and appeared more like the pedicle of a villous tumor than anything else; no trace of a tumor was visible, however. No microscopical examination was made of this growth.

Soon after the dysentery was checked I began to suffer with symptoms of stricture of the rectum, and in the latter part of March, 1886, I started north to consult experienced surgeons. Early in April I was examined in Washington, D.C., by Dr. J. Ford Thompson, and he found a very close stricture commencing about three and one-half inches from the anus. The stricture was so tight at this time that he could not penetrate it with his smallest bougie. Dr. A. F. A. King was present one time at Dr. Thompson's office and examined me, and, although he evaded giving a positive answer, I fully understood that he agreed with Dr. Thompson in his diagnosis, viz., that if the stricture were not already of a cancerous nature, it would become so very soon. This opinion Dr. Thompson declared to me and to my brother on several different occasions. Dr. Thompson sent me to Dr. Sands for examination. You will find Dr. Sands's opinion fully expressed in a copy of the letter inclosed, written to my preceptor (from whom I took a letter of introduction). This same exuberant growth removed from the lower margin of the stricture by Dr. Sands forms the foundation for all the examinations made by the microscopists (that of Dr. Edward Schaeffer was given in writing, and is inclosed). I was examined next by Dr. L. A. Stimson, and he said, at once, "The growth does not feel like a cancer"; but he declined to commit himself in a diagnosis until he had had the opportunity to dilate the stricture and explore it thoroughly. I consented to the examination under ether, and, at my request, Dr. Chas. B. Kelsey was present at the examination, in the Presbyterian Hospital, May 18th. In attempting to dilate the stricture it was torn, and linear rectotomy was performed at once. Dr. Stimson's opportunity for examining the stricture thoroughly was better than that of the others, who did not ask for an examination under ether. He said the stricture involved about one and one-half inches of the bowel, and was papillomatous in nature. Dr. Kelsey agreed with Prof. Stimson's diagnosis, and based his own on the microscopical opinion given him by Prof. Stimson.

I was very sick after the operation of rectotomy, caused, I have always thought, by having Fowler's solution of arsenic suddenly discontinued, which I had taken for some time immediately preceding the operation, in large doses, according to the direction of Dr. Sands. I was removed from the hospital to my brother's, in Washington, D. C., and after three weeks was able to be out, and Dr. Thompson commenced to dilate the stricture with bougies. On July 4th I was examined by Prof. J. McLane Tiffany, of Baltimore, who made both a digital and microscopical examination, and he said, whereas he did not regard the stricture as cancerous at the time he examined me, yet he thought it would undoubtedly become so in time, as my case had started in just the way most of the cancers of the rectum commence. On July 5th I was examined by Dr. D. Hayes Agnew, who pronounced the stricture cancerous just as soon as he had made the digital examination, and he confirmed his diag-

nosis with the microscope, declaring it cylindrical epithelioma (agreeing very nearly, you see, with Dr. Sands's diagnosis).

I was examined by Dr. Edward L. Keyes soon after I first met you, in September, and he said he would pronounce the stricture benign, unless the microscope declared otherwise. He saw no objection to trying electricity, but could not recommend it as being likely to benefit me any. The microscopic specimens prepared by Dr. Edward M. Schaeffer from the exuberant growth removed by Dr. Sands were examined by Drs. Biggs, Geo. L. Peabody, and Prudden (of P. and S.), and they all declared the growth benign; but Dr. Prudden added that it would, in all probability, become malignant in time, thus agreeing nearly with Dr. Schaeffer's examination, as you will notice.

Now, all these diagnoses were made up entirely from the case, as no two men whom I consulted knew anything of the opinion given by any other man in the case (excepting Drs. Kelsey and Stimson) until his own opinion had been given.

I hope you remember the very favorable impression my improvement caused Dr. J. Ford Thompson to form of the electrolytic treatment. When he examined me, in March of 1887, he said, "You are a great deal better than when I saw you last, and your improvement can be due to nothing else you have tried save the electricity." "You have, indeed, been very lucky in trying it," he added.

I hope you will be able to find in my letter about what you wish; but, if not, do not hesitate to command any other information of me which I may be able to give you. I am only sorry I could not have remained in New York, and have been continuously under your treatment, when by now I would have been either entirely well or so much improved that even Dr. Keyes himself would have to admit that it had accomplished what he had several times declared it would not accomplish.

Dr. Kelsey, who was, at the time of my leaving New York, sanguine over the prospects of having found a new remedy in electricity for stricture, told my preceptor, shortly after he called on you in New York, last winter, that he had since given electricity a thorough trial, and that it was an entire failure. Dr. Wm. H. Thomson advised me to continue the current, as the principle was a correct one. No change in stricture since last writing.

Hoping this will find you enjoying the very best of health and prosperity, I am,

Very truly yours, G. E. W.

Inclosed were several letters declaring the rectal stricture a carcinoma. Dr. E. M. Schaeffer closes his microscopical report as follows: "On the whole, then, I regard the prognosis as unfavorable, so far as based upon the probabilities of the direction which the growth may take in future." The letter of Dr. H. B. Sands begins: "I have examined Mr. W. carefully, and have come to the unpleasant conclusion that his disease is malignant."

The patient came back to New York in the fall of 1889, when he had more electrolytic treatment. October 6, 1889, examination with the endoscope. The rectal tube passed very easily to five and a half inches up; no stricture was found; the rectum looked healthy. October 13th, the largest rectal electrode passed very easily. During the last week the patient had been re-examined by Drs. Kelsey and Stimson separately, and both gentlemen acknowledged that the patient was practically well. He has gained flesh, and is well in every particular.

In the former report this case was modestly claimed only as benefited, while time has shown that it is a perfect cure, without any relapse in six years. The patient has been re-examined every year; the last time in Washington, in April, 1892, and found to be perfectly well. A

bulb in the rectum could be dilated to over five inches in circumference, and there was no trace of any stricture.

The remaining cases (9 to 12) were treated in the regular way as described before, and need not be related in detail. They were cured. One was observed one year, two cases four, and one case five years, in which time no relapse had occurred.

Dr. Samuel Benton, of London, who has reported cases of rectal strictures treated successfully by electrolysis, wrote from London, June 1, 1889:—

"DEAR DR. NEWMAN: The two patients whom I treated for stricture of the rectum by electrolysis, and published the cases, have remained well and are permanently benefited. I have not had any more cases suitable for this method of treatment, or I should certainly use it again," etc.

Dr. Earle (Case 14) reported his case to the Medical and Surgical Society of Baltimore, and kindly sent the author the notes which have been published.

In recapitulating the facts in these cases, we find some interesting items. It seems that females are more inclined to have rectal strictures, as out of twelve cases only two were men. Their ages were mostly between 30 and 40, the youngest 24, the oldest 62 years old. The two males were comparatively young men, respectively 23 and 26 years old. Eight cases were single strictures, four had multiple strictures. The duration of the malady was from six months to twenty years; the causes varied, but hæmorrhoids and constipation were important factors; other causes were syphilis, venereal, enteritis, and dysentery. It is certain that a rectal stricture may follow any inflammation of the rectum. One case had the complication of five fistulæ, commencing in rectum and ending externally in different parts, in vulva and gluteal region. As soon as the stricture was cured the fistulæ healed up without any treatment; two had medical and the balance surgical treatment, six of which had been operated upon with the knife. In not a single case had the previous treatment been successful; some were entire failures, and all that can be claimed in some exceptional instances was a temporary relief followed by relapses. Even the most sanguine operator will admit that proctotomy must be followed by the use of a rectal bougie at regular intervals. If we now compare all other methods formerly used with the treatment by electrolysis, we find that the latter has improved every case at least, and in the majority of cases has effected a cure. The Cases 5 and 6 were certainly improved, but in the end may not prove satisfactory: one patient had too many complications; and while the author has not heard from her, he knows she could not have been permanently benefited; the second case (No. 6) was an aggravated case, and the patient too poor to attend to herself, or even to come regularly for treatment. This case was then operated upon, and she had to use a rectal bougie regularly, by which means she kept the stricture from closing up again; but after

four years had a relapse with complications, and finally died. Case 8 is a perfect cure, and remained well after six years; which fact has been graciously acknowledged by several surgical authorities; while a papillomatous growth, by some pronounced carcinoma, complicated the case to such a degree that a cure could scarcely be expected by any treatment. While two cases were improved, ten cases were cured by the electrolytic treatment, and, as far as known, no relapse had taken place, which were from one to ten years respectively; except one case, in which nothing has been heard from. The best results were achieved from the same method as used in the treatment of urethral strictures by electrolysis; that means by metal bulbs as negative, weak currents at intervals. But it is in the nature of the parts treated that the current can be applied stronger and oftener than in the urethra.

Advantages of the Electrolytic Treatment.—1. The percentage of cures without relapses from reliable statistics, proven by documentary evidence and witnesses, shows electrolysis, in the treatment of rectal strictures, to be the best method. 2. While failures may occur in a small percentage, the electrolysis will always cause at least an improvement, even when all other means have failed. 3. In carcinoma the electrolysis will benefit, and if a cure is impossible it will always alleviate the intolerable pains. 4. The fibrous inflammatory stricture affords the best chance for a cure. 5. The proper mode of treatment is by a metallic bulb as negative pole, weak currents, intervals of four days to a week. Some cases may need shorter intervals between *séances*. 6. The treatment, as a rule, causes no pain and no hæmorrhage. 7. If cured once, no relapse takes place, and no after-treatment with bougies is needed.

Having carefully considered at some length the details and treatment of rectal strictures by electrolysis, the subject is now left for the kindly consideration of the profession.

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Strictures in Other Parts of the Body.

All strictures in any other part of the body yield to electrolysis, and must be treated according to the same principles and in the same manner as urethral or rectal strictures, as described before. We meet with strictures in the female urethra, nasal cavity, Eustachian tube, lachrymal duct, and in the œsophagus.

Stricture of the Female Urethra.—They certainly happen, but are rare, on account of the anatomy and physiology of the organ. Little or no reference is made to it in text-books, and only a few cases are reported in the literature. Only recently Dr. F. N. Otis has reported four cases,[1] and at the same meeting Dr. R. W. Taylor stated that he had seen a number of cases, some as small as No. 4 French. Boucher[2] reports one case, Boehm[3] mentions another, and Velpeau cites three. The writer has reported several cases[4] treated and cured by electrolysis:—

Case 1 happened in a widow, aged 35, who had adenitis, syphilitic dyscrasia, with indolent ulcers and tertia periostitis. After constitutional treatment all syphilitic symptoms disappeared, but, nevertheless, the stricture remained just as bad as before, with a very small stream, straining and painful micturition, and on examination an organic stricture was found. A sound (No. 5) passed scarcely one inch, and then was arrested. Five applications with electrolysis cured the stricture. The patient remained under observation, and was re-examined after one and two years. No relapse. Twelve years afterward the patient was seen, and she stated that she had remained well.

Case 2.—Stricture of the urethra; granular urethritis; retroflexion of the uterus; endoscopic examination; electrolysis; cure. Sixteen months after treatment Dr. Murray wrote: "After some trouble I was able to get some information regarding Mrs. D.'s case. I have been informed that your treatment made a complete cure. She has removed to Illinois, and had a young son lately," etc.

Case 3 was cured by electrolysis. One year afterward patient enjoyed good health, without having had the slightest relapse.

Case 4.—Stricture of the urethra; fibrous bands and partial urethrophraxis; electrolysis; cure. The lady has been kept under observation sixteen months, and remains well. The cure is complete and permanent of what may be called an unusually bad stricture. Five operations were necessary before a satisfactory result could be recorded.

Several other cases are similar to the above. The *modus operandi* in these cases is exactly the same as in the treatment of strictures in the male urethra; a galvanic battery is used. The negative metal-electrode applied to the stricture, mild current, long intervals, and gently guiding the electrolysis without any pressure or force. The result of the treatment was invariably a cure without a relapse, while other means had failed.

[1] New York Medical Record, September 26, 1891, p. 362.
[2] Gazette des hôpitaux, No. 16, 1865.
[3] Berlin Central-Zeitung, No. 84, 1860.
[4] American Journal of Medical Sciences, October, 1875.

Strictures in nasal cavities have been treated likewise with electrolysis. The writer has had two cases, which have not been published. The negative pole is applied to the stricture and a weak current used, of about 3 milliampères. Gorecke's method is mostly known.[1] Hypertrophy of the inferior turbinated bone is better treated by platinum needles as the negative pole.

Lachrymal Strictures.—These strictures have been treated by oculists with sounds as gradual dilatation. Electrolysis is used in the same way; the sounds introduced into the duct are connected with the negative pole of a galvanic battery, while the positive sponge-electrode is held in the palm of the hand; very weak currents must be used, from 2 to 3 milliampères. To place the positive pole in the neck of the patient, as some operators recommend, is objectionable, because it may irritate sensatory nerves.

Strictures of the Eustachian Tube.—Mr. Cumberbatch, the aural surgeon of St. Bartholomew's Hospital, in London, writes as follows concerning the operation: "Our experience is at present too limited to be able to say what cases of chronic catarrh of the middle ear are most likely to be benefited by this new method of treatment. That strictures of the Eustachian tube which do not yield to the ordinury methods can be cured by the use of the electric bougie we have proved."

W. E. Steavenson describes the *modus operandi* as follows[2]: "Electrolysis of the Eustachian tube is performed in much the same way as the electrolysis of the other mucous passages. A pad connected with the positive pole of a galvanic battery is moistened and placed in the patient's hand. The Eustachian catheter is then passed along the nostril and guided into the tube; the bougie, already attached to the negative pole of the battery, is passed along the catheter and Eustachian canal as far as it will go, until it meets an obstruction. The current is then closed. The electric current is then slowly increased until a strength of 4 milliampères is obtained. A frizzling noise will be heard by the patient in his head, usually similar to the frying of fish; and the operator, by approaching his ear to the catheter, can often hear the crackling produced by the frequent breaking of minute bubbles of gas. The electrolysis is kept up for four minutes, and usually before the expiration of that time it is possible that the obstruction can be removed; it will be found that the bougie can be pushed on for a small distance, sometimes for its full length."

The operation has now been performed a large number of times without any unpleasant experience; nor has the treatment anything more than very temporary discomfort to the patients. In those cases in which the deafness has been due to a simple obstruction of the Eustachian tube, the results have been most encouraging.

[1] Medical News, Quarterly Epitome, March, 1883, p. 117.
[2] Electrolysis in Surgery. London: J. & A. Churchill, 1890.

At a meeting of the Académie de Médecine, March 11, 1884,[1] M. Mercier read, in his own name and that of M. Garriçon-Desarénes, a note upon the treatment of stricture of the Eustachian tube by electrolysis. The operation consisted in passing a fine silver sound into the Eustachian tube and a small olive-shaped electrode into the external auditory meatus. A feeble current is then passed, the sound is gradually pushed on, and the stricture disappears.

Stricture of the Œsophagus.—Brilliant results by electrolysis in this affection have been recorded. Prof. J. A. Fort has had excellent results with linear electrolysis, in three cases of stricture of the œsophagus, and recommends a trial of the method. He employed an electrolyzer similar to that used by him in stricture of the urethra. The positive pole was placed over the abdomen and the negative carried down to the stricture. The sittings lasted several minutes, and were repeated in two or three days. The applications were usually followed by increased frequency of the pulse, which subsided as soon as the current was interrupted; contractions of the facial muscles, pains in the ears, and disturbances of hearing. Two of the patients suffered from fibrous strictures, and one from carcinomatous infiltration. The results of this treatment were very good. The patients, who previously were unable to swallow even liquid food, were able to swallow liquids after the first application and solids after two or three sittings. Hæmorrhage and other disagreeable symptoms, such as are known to follow mechanical dilatation, were not observed.—*Gazette des hôpitaux.*

T. F. Frank reports a case successfully treated by electrolysis,[2] which, however, appears to have been more a spasmodic stricture. F. F. Dickman,[3] of Fort Scott, relates an interesting case, which, however, was fatal in the end, through accidental complications. Prince and Butler were pioneers in reporting cures by electrolysis. E. T. Painter, of Pittsburgh, reports one successful case.[4] He used the positive pole in the œsophagus and the negative in the hand; twenty-five applications were made in three months, and *séances* were held three times a week, each time lasting six to twelve minutes. One case of tumorous stricture of the œsophagus cured by electrolysis was reported by D. S. Campbell, M.D., in the *Transactions of the Michigan State Medical Society*,[5] June 14 and 15, 1888.

The writer has treated several cases with immediate relief. On June 5, 1888, H. D., aged 59, presented himself with a stricture of the œsophagus. He was very emaciated, and had not been able to take meat or any solid food for the last three months; could swallow water with great difficulty. After one *séance* by electrolysis he could drink well and did

[1] Gazette des hôpitaux, Paris, 1884, lvii, 28.
[2] Archives of Electrology and Neurology, vol. ii, May, 1875, p. 23.
[3] Kansas Medical Record, May, 1889, p. 174.
[4] Medical Register, October 13, 1888, p. 344.
[5] New York Medical Record, May 4, 1889.

eat porridge of oatmeal; after the second application could eat meat and felt much improved. The stricture was thirteen inches down from the teeth. Electrode passed and advanced to fifteen inches. Patient was so much benefited that he could return to Liverpool, and he has not been heard from since. In this treatment it is important to use as the negative pole an electrode which is very flexible and passes down the passage easily without hurting the patient; the electrode should be more flexible than the ordinary œsophageal bougie. The positive pole is placed best in the hand of the patient, or on any part of the body. A weak current, from 5 to 10 milliampères, acts best. If the stricture is not malignant, a cure is almost certain in every case. Only one peculiar case may be mentioned, in which electrolysis produced a cure in conjunction with gastrotomy. This case was reported by Professor H'jorth, of Christiania, at the International Medical Congress in Copenhagen.[1] The stricture was caused by the patient swallowing an alkali. The contraction following was of such a nature that no sound would pass below the cricoid cartilage, and swallowing was nearly impossible. Gastrotomy was resorted to, and electrolysis applied at the part. The current was commenced with 5 cells, gradually increased to 15 cells. After one hour the electrode bougie suddenly passed through the stricture. The second application was made after twelve days, after which the stricture was so well cured that the patient could eat and swallow both solids and fluids, and a Charrière bougie No. 19 passed through the former stricture both ways, from below and above. Two weeks later the gastric fistula was closed by operation.

HYPERTROPHY OF THE PROSTATE.

In the diseases of the prostate, and particularly hypertrophy, many cures have been reported by different methods of electricity. Great caution and patience are required to successfully handle such cases. The usual means formerly employed, such as internal medicine, injection, destruction, incision, enucleation, prostatotomy, as a rule, gave unsatisfactory results; more severe operations by suprapubic cystotomy, as introduced by Belfield[2] and Hunter McGuire[3] since 1886, were improvements and have cured some patients. There is no method yet which will invariably cure, because some hypertrophies have assumed too large dimensions, have painful complications, and have undermined the constitution of the patient, already infirm from old age, beyond any redemption.

[1] New York Medical Record, September 6, 1884.

[2] "Operations on the Enlarged Prostate," by W. T. Belfield, M.D., Chicago. American Journal of Medical Sciences, November, 1890.

[3] Hunter McGuire: "Operative Treatment in Cases of Enlarged Prostate." Virginia Medical Monthly, October, 1888.

From the literature on this subject it will be seen that various methods of electricity have been used which will be considered under the following divisions:—

A. GALVANO-CAUTERY.

1. The regular (slow) method by flashes of Newman's galvano-cautery sound.
2. Bottini's rapid method in one *séance*.
3. The radical cure by operation of suprapubic cystotomy and removal of the hypertrophy by galvano-cautery.

B. ELECTROLYSIS.

4. Electrolysis by mild currents.
5. Massey's method per urethra and rectum by strong currents.
6. Galvano-puncture per rectum.

1. Regular Slow Method by Flashes of Newman's Galvano-Cautery Sounds.—This galvano-cautery sound was first presented to the profes-

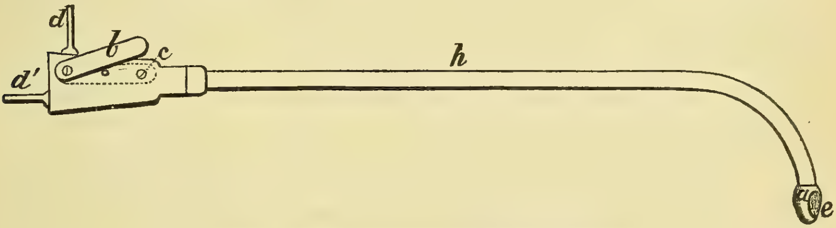

FIG. 11.—THE GALVANO-CAUTERY SOUND.

a, fenestrum, inside of which is the burner *e*, platinum wire; *h*, tube; *d* and *d′*, pins to be connected with the electrode cords; *b*, current-breaker; *c*, screw to be connected with current-breaker, *b*.

sion at the meeting of the American Medical Association held in St. Louis, June 5, 1886; and at the Ninth International Congress held at Washington, D. C., in September, 1887, the instrument was shown in a much altered and improved form, and its utility demonstrated.

The instrument is catheter-shaped, of smooth, polished metal, with a short curve at one end; at this end is a fenestrum, *a*, in which is placed the platinum wire *e*, the burner to be heated. A serpentine form is best for this wire; each end is firmly attached to one of the two copper rods inside the tube, *h*, representing, respectively, the positive and negative poles. The other end of the instrument is straight and forms the handle, in which commence the copper rods, each of which is fastened to one of the pins or heat-conductors, *d* and *d′*. These two pins are connected with two electric cords by binding-screws. The other ends of the two electric cords are fastened, respectively, to the positive and negative poles of the battery. The current-breaker, *b*, is movable, and when set straight and pressed firmly down on the screw, *c*, electricity is evolved and the burner, *e*, instantaneously heated.

The recent improvements consist in (1) having the handle in one light, convenient piece; (2) having the current-breaker under the immediate control of the index finger; (3) having the fenestrum filled up, whereby the instrument is more thoroughly insulated and less liable to become heated; (4) having the tube filled up, thus preventing it from getting wet or blocked with *débris* inside.

The Battery.—We must have a battery so constructed as to give a certain quantity of electricity of a fixed potential, suited to the work to be done, and to the instrument; too high a potential will melt the platinum wires, or cut the tissues like a razor; on the other hand, too low a potential will fail to heat the wire and not be effective. Therefore it is imperative to adjust the electricity necessary for our work and instrument, for the same quantity of electricity under the same circumstances will always do the same work. The best instrument to fulfill all indications required is unquestionably a storage battery, the potential being regulated by a rheostat. The author has used for four years an accumulator regulated by a rheostat made by Waite and Bartlett, and the instrument is still good. The next best thing is Dawson's cautery battery, which is very light and portable, and for short operations polarization can be prevented. It is made by George Tieman & Co., New York.

If the wire is heated slowly, becoming warm and gradually hotter till the desired heat is obtained, it shows that the instrument is faulty in its construction; consequently, must be imperfect in its results. In experimenting with the instrument on mucous linings, we find that a galvano-caustic application of the same power acts differently according to the length of contact with the tissues. Thus, the effects can be regulated from a light blush to the total destruction or even amputation of the tissues.

It is a misconceived idea of many that the galvano-cautery necessarily burns, destroys, and is followed by cicatricial tissues. Nevertheless, this is a favorite objection of some ignorant persons and enemies of electricity. If the operator bungles or wishes to destroy, he can; but the expert will not. It is well known that eminent neurologists apply galvano-caustic directly to the faces of young ladies, without ever causing marks. All depends upon the manner of application. Even deeper applications on mucous linings may cauterize without destroying. Voltolini, Carl Michel; Shurly and Yeamans, of Detroit, and many others, have applied the cautery to the nasal and pharyngeal cavities with great success. Therefore, it is evident that different methods can be instituted with the instruments, and applied for various purposes to different parts.

Modus Operandi.—The galvano-cautery sound is connected with two electrode cords, which are then attached to the two binding-posts of the battery, each respectively to one pole. The fluid in the cells must be of the right standard, and all the machinery in perfect order. When

all in readiness, the author invariably tries the instrument with a short flash. No matter what assurance he has of the perfection of the appliances, this little precautional trial precludes any failure. The prostatic portion to which the cautery is to be applied must have been ascertained, and the distance is then marked on the instrument by a small rubber band. The patient, according to his preference, may stand erect, be on an operating-table, or in bed. The instrument is then introduced so that the fenestrum with its platinum wire is in contact with the part to be cauterized. The operator will know by touch when the instrument is in the right place, and the measure will corroborate the correctness of the situation. One hand holds the instrument in this place firmly, and then the current-breaker is placed in a straight line and pressed firmly upon the screw, a flash follows, and the raising of the finger from the current-breaker disconnects the current. If indicated, several flashes in succession may be given or repeated in different places. In a moment the operation is done and the instrument is withdrawn. It causes no pain, and in some instances the patient scarcely believes that anything has been done. He is able to walk about, and is not detained from business. In cases of very irritable patients, the author has used cocaine injections, but it was scarcely necessary. The *séance* should be repeated in about three days, or even in two. The instrument must be kept scrupulously clean, for the cautery will fail if there is dirt between the connections.

The question now arises, How does this method bring about a cure? The end sought is, first, to remove the obstruction so that the bladder can discharge all the urine, and at regular intervals; and then, in order to make the cure radical, to reduce the prostate to its normal size. The theory is that the cautery first acts as a tonic and next as an astringent; the mucous lining shrivels up, the glandular tissue contracts, and by shrinking the size, if diminished, the stimulation gives new life and healthy action. Each repetition of the operation acts similarly, and perhaps on another part of the hypertrophy. The operation must be continued till the cure is effected. Care must be taken not to overstimulate, and cause prostatorrhœa, prostatitis, etc., thereby creating or aggravating the very ailment sought to be cured. The cautery must be given just severely enough to accomplish the object, and no more. If the cauterization is too prolonged and too deep, the glandular action is overtaxed and weakened, and will be followed by a prostatorrhœa which takes a long time to cure. At the same time an inflammation is created, which causes pain and swelling, and, at last, the too greatly cauterized tissue will slough away and may cause septicæmia.

This method of treatment of hypertrophied prostate with the galvano-cautery sound I prefer for the following reasons: It has benefited or cured all cases under observation; a reasonable time has passed without any relapse; it has caused no pain, no detention from business

or pleasure; no untoward after-symptoms or circumstances have ever occurred. For these reasons, I prefer this slow method described. Cases have been reported.

2. Bottini's Rapid Method in One Séance.—Musatti and Bottini are the pioneers of this method, and particularly the latter has constructed his own instruments and reported, from 1885 to 1891, many successful cases. His procedure consists in the destruction of the obstructive part of the prostate in one *séance.* His galvano-cautery instrument is introduced in the urethra until it is arrested by the offending part. Then the galvano-cautery is applied and kept up until it has burned its way through and made a passage into the bladder, thereby destroying the enlargement. The patient is kept in bed afterward, a catheter for drainage kept in the urethra until the *débris* of the destroyed part is removed, the parts healed, and at last voluntary micturition established. Meanwhile the patient suffers, is laid up, and according to records it lasts about twenty-six days before urine can be voided voluntarily.

Bottini's instrument is clumsy, unhandy, and needs so large a galvano-cautery battery as to be too heavy to be moved about. His instrument is shaped like Heurteloup's lithotrite, without any curve, the end having only a short coudée like Desormeaux's fenestrated male endoscopic tube. Such an instrument is exceedingly difficult to introduce, and in many cases of hypertrophy unintroducible. The intention is to push this instrument into the bladder, over and beyond the enlargement of the prostate, then to reverse it inside, so that the beak is turned downward. The galvano-cautery knife is *à la cachée* inside the beak, and moves outward by turning a dial on the handle, while the battery heats it, thereby making a central cut and division in the obstructing prostate. While the idea of the operation is excellent, yet there are many objections to this method. It is a very severe and uncertain operation, with an immediate shock, followed by pain, much suffering and inflammation, which may cause a new obstruction, partly by spasm of the bladder and partly by the *débris* of the destroyed tissue. Mr. Fenwick made the same objections at a meeting of the Medical Society of London, January 11, 1892. At that meeting Mr. Bruce Clarke read a valuable paper on the radical cure of prostatic obstruction by the galvano-cautery, and reported four cases. He has kindly sent the author an abstract of said paper, as follows:—

Abstract of Mr. Bruce Clarke's Paper; Operations.—After some general statements on prostatic enlargement, and after drawing special attention to the method of diagnosis of varieties of enlarged prostate, the author went on to treatment. There are, practically, two kinds of enlarged prostate: 1. The big growths, which may be as large as an orange. This form can be diagnosed with fair certainty by finger in rectum and instruments in bladder, and also by increased length of urethra before reaching water. This class is quite unsuitable for galvano-

cautery (Bottini) or per urethram, but demands suprapubic operation and removal, etc. 2. The slight prostatic enlargement, where perhaps only a small fold of mucous membrane, with but little general enlargement, is present. Diagnosis, same means as in previous case. These cases yield excellent results. Account given of four cases, three cases radically cured, one much improved; three cases shown at medical society:—

Case 1.—W. P., aged 73. Treated June 20, 1890. Duration of symptoms, eleven months. Residual urine, average ten ounces. Galvano-cautery, five seconds. Catheter had in forty-eight hours. Sloughs passed a few days later; well in three weeks.

Case 2.—I. P., aged 58. Residual urine, fourteen ounces. Duration of symptoms, four months. Treatment ditto. Left hospital in twenty-six days.

Case 3.—A. B., aged 64. Residual, eleven ounces. Duration of symptoms off and on for ten years; had prolapse of rectum as well. Treatment ditto. In six weeks completely emptied his bladder.

Up to present time all these cases can completely empty their bladder without catheter.

Case 4.—O. S., aged 67. Had stricture as well, which was first treated by electrolysis. Residual urine, twelve ounces. In November, 1891, galvano-cautery of prostate. Still has four ounces of residual urine, and passes water more easily, but there is a good deal of bladder irritability at times.

The exact method is the same as that described by Dr. Marotti, in the *British Medical Journal*, last summer, and the instrument was got from Italy; accumulators used to get current.

3. Radical Cure by Combination of Suprapubic Cystotomy and Galvano-Cautery.—This operation is indicated—in fact, we may say, peremptorily demanded—when the patient is in immediate danger of succumbing, as no time is left for a slower method of procedure. This state has arrived when the hypertrophy causes absolute retention of urine, and there is no possibility of gaining an entrance through the obstruction, so as to evacuate the bladder. Complications have generally taken place and the fatal termination is within a few hours, either by rupture of the bladder or uræmia, as even aspiration of the bladder would only give temporary relief.

The radical operation proposed for such a condition is not free from danger, but, as the patient without severe measures will succumb in a short time, the operation cannot decrease his chances of living, but, on the contrary, does increase them, if performed with antiseptic precautions and in accordance with the most approved methods. The operation consists in the removal of the hypertrophy *in situ*—either in part or entire—by galvano-cautery. It can be done by a burner, or by the platinum sling; access is gained by suprapubic cystotomy. The improvements in the technique of suprapubic cystotomy by Belfield, Hunter McGuire, Kuemmel, Morris, and others have reduced any danger to a minimum.

Mr. A. F. McGill, of Leeds, in opening a discussion[1] at the section of Surgery, British Medical Association, August 16, 1889, remarked that suprapubic prostatectomy was preferable to a urethral or perineal operation. The urethral operation was unsatisfactory; it was founded on faulty anatomy, for in only four out of the twenty-four cases he had tabulated was there anything resembling a bar at the neck of the bladder. The suprapubic operation was also more generally applicable; in only three of the twenty-four cases in his table could the perineal operation have been done. He also considered the suprapubic operation more safe than perineal section. Most authorities will agree with Mr. McGill.

The advantages of the galvano-cautery over the knife are (1) that it avoids hæmorrhage, also secondary hæmorrhage; (2) it leaves no raw surface exposed; (3) it heals better, and (4) avoids septicæmia. The statement of some reports, that in prostatotomy with the knife hæmorrhage does not take place, cannot be accepted, as the history of cases shows that primary as well as secondary hæmorrhage does occur, both of which are entirely avoided with galvano-cautery.

4. Electrolysis with Weak Currents.—Electrolysis has been used with favorable results, and cases reported accordingly. The writer has practiced it in the same manner as in strictures of the urethra, and often applied a flat metal-electrode as negative pole per rectum against the prostate; with great care and very mild currents, good results followed; but as the galvano-cautery sound gave him universal success, he never has advocated a method by electrolysis.

Dr. W. E. Steavenson, of London, has established a method and constructed his own instrument; a citation from his work[2] will therefore be in place here:—

"For this purpose I have had some electrodes made after the manner of those used for the electrolysis of stricture, but, instead of the ends being made entirely of metal, I have had them of ivory, with phalanges of metal imbedded in one side, so that the metal would be on the convex surface of the ends of the electrodes. By this means we insure that when the electrode has been passed along the urethra the metal phalange shall come in contact with the prostatic bar or obstructing hypertrophical part of the prostate. The electrode is connected with the negative pole of the battery, the positive pole being placed on some indifferent part of the body; the circuit is then closed and a weak current of 5 milliampères is employed; by this means a furrow or groove is made on the surface of the enlarged prostate by the action of the current. The result has been such as to encourage the hope that this may prove a very useful form of treatment. The operation should not be prolonged for more than twenty minutes, and on the first few occasions for about half that time unless the electrode passes into the bladder sooner. Should this be

[1] British Medical Journal, October 19, 1889.
[2] Electrolysis in Surgery, London, 1890, p. 106.

the case, I would advise that all further attempts be suspended for at least a week, and then repeated if no indication to the contrary has arisen."

Dr. Bryce, of Richmond, Va., has also used mild currents, and Dr. John D. S. Davis, of Birmingham, employs the same in different pathological conditions of the prostate.

5. *Electrolysis by Strong Currents.*—While others have used stronger currents, Dr. G. Betton Massey, of Philadelphia, has very recently begun a new treatment of hypertrophy of the prostate gland. He calls it "the swelling method." With the electrodes in place, the active electrode within the urethra or rectum and the indifferent on the abdomen, the galvanic current is turned on by means of his controller until a decided sensation is produced, or the meter shows a desirable dose, and is turned off again in a few seconds, the procedure being repeated eight or ten times. He uses as much as 70 milliampères, though each case must be a rule to itself in this particular. As the growth diminishes the sensitiveness of the prostatic urethra will increase until finally from 5 to 15 milliampères will be the limit. The negative pole has been used as the active. He makes his own instruments. After each galvanic application to the prostatic urethra the instrument should be left in place, and a primary faradic current turned on in a swelling manner. The instrument is now withdrawn and a similar application made to the exterior of the prostate by an olive electrode in the rectum, and the same electrode on the abdomen. The rectal treatment may be employed daily, and is at times efficient of itself alone, but the urethral method must be used at intervals of from four to seven days only. Dr. Massey reports complete cures. This method is of so recent an origin that no comment can be made on it.

6. *Galvano-puncture.*—Instead of the negative metal bulb, in this mode of treatment a needle is used and thrust into the prostate. The best needle is made of platinum, insulated to within a short distance of its point. An electrode placed on the abdomen, to close the circuit, is connected with the positive pole of the galvanic battery. Biedert, of Hanau, reported five cases in which the hypertrophy was reduced. Leopold Casper read a paper in 1888, before the Berlin Medical Society, and claimed improvement in four cases. He uses the negative needle to the hypertrophy per rectum. He claims that the method is curative and, if carefully executed, harmless.

The prostatic electrolyzer is the invention of a scientific gentleman of Philadelphia, and constructed in harmony with sound principles. The negative electrode is a metal bulb introduced per rectum to the prostatic enlargement, while the positive, a small sponge-electrode, is held in the perineum. The two poles are rather near each other, otherwise the instrument is constructed according to principles mentioned above.

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ABSCESSES; ADENOMAS; ADIPOSE TUMORS; ANEURISMS; CALLOSITIES; HÆMORRHOIDS; TORTICOLLIS; SPECIFIC AND MALIGNANT DISEASES OF THE RECTUM, AND ULCERATIONS.

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Abscess.

An abscess is defined as a collection of pus in the tissues. If such collection be in a preformed space, such as the Fallopian tubes, the pleura, etc., it is not called an abscess, but takes the name of the locality, —pyosalpinx, pyothorax, etc. At the same time, some of these forms are amenable to treatment with electricity, more especially pyosalpinx. This, however, coming as it does under another section of this work, will not be considered here.

Varieties of Abscess.—We have two varieties of abscess with which to deal,—the acute and the chronic. An acute abscess is generally found in the connective tissue, and the suppurative stage should be prevented if possible. We may thus have the anomaly of treating an abscess when it does not exist. I shall speak of such a lesion as *threatened abscess.*

In the initial stage the local treatment will be the same, whether the lesion shall be due to constitutional causes or of traumatic origin. If constitutional, in addition to the local treatment, general tonic faradization must be used, in order to tone up the system. This is done as follows: The patient is prepared for treatment by removing the clothing to the under-garments if a male, and as much as may be necessary if a female, protected with a sheet or blanket, and seated upon a well-wetted sponge connected with the anode or positive pole of a good faradic battery. For this purpose the current called C. D. of the Kidder coil I find the best. With the cathode go over the back, chest, sides, and abdomen, using a pleasant current, just strong enough to get a full stimulating effect. I have found that better effects are realized from faradization when the whole coil is under the influence of the induced current,—*i.e.*, when the tin tube covering the coil is fully withdrawn, and the current governed by means of the controller. Treat the trunk for five minutes; and if the lower limbs are to receive attention, reverse the current so that you use the anode upon them. The current thus passes up the sensory nerves, acting as a powerful stimulant tonic. Let the sitting not exceed ten, or at the most fifteen, minutes.

When dealing with threatened abscess, the formation of pus should

be prevented if possible. This may be accomplished if taken early. Make frequent applications with the galvanic anode directly to the inflamed parts with a suitable electrode. This may be of carbon covered with absorbent cotton, wetted, it may be, in a solution of ammonium chloride. Place the cathode, or negative, at some distant point, that the full polar effect may be had at the anode. If the parts are excessively sore and painful, as they are very apt to be, a 10-per-cent. or 20-per-cent. solution of cocaine may be used on the anode instead of the ammonium chloride. Use a current-strength of from 5 to 10 milliampères, and let the application last for from three to five minutes, and repeat daily. Mild currents and frequent applications will accomplish more than strong currents at long intervals. In fact, with too strong a current too much reaction results, and the inflammatory processes intensified rather than retarded.

The location of an abscess will determine whether it is to be treated with electricity or by ordinary surgical methods. For instance, an alveolar abscess, an abscess in the liver, kidneys, or spleen, would not be considered suitable subjects for electrical applications as usually understood. The electro-cautery may be used in some of these cases to great advantage. This is especially the case in that specific class of tumors or abscesses known as buboes. These may be quickly opened with a cautery-knife, and the pyogenic membrane destroyed by the same means. This is a radical and effective method of treating a bubo.

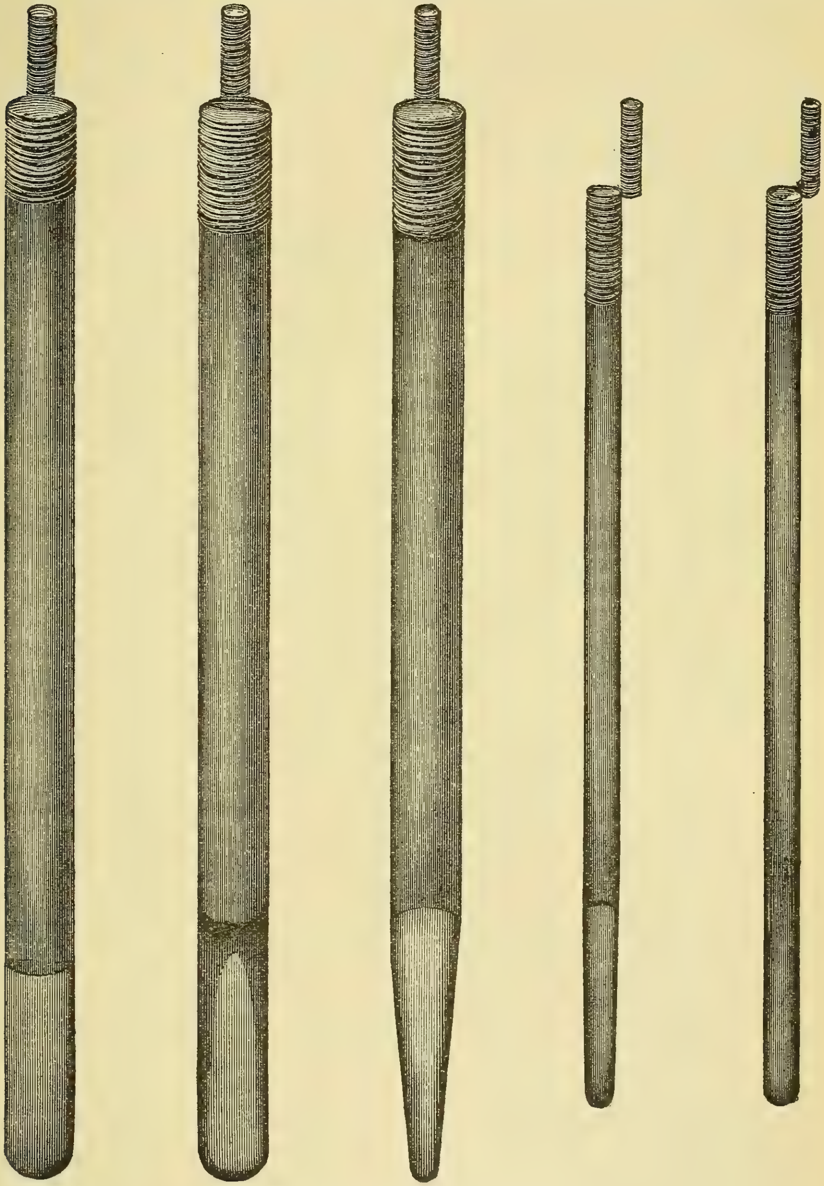
THREATENED MAMMARY ABSCESS.

In such a lesion, if taken early and the treatment be thoroughly carried out, good results may be expected. A large electrode should be used, one covering the entire breast being preferable. For this purpose a plate of pure tin may be cut into the shape and form of a pattern for a breast-plaster, a suitable attachment made, and the whole covered with absorbent cotton. This may be wetted in the solution of ammonium chloride or of cocaine, as before stated. Use the galvanic anode to the inflamed part, with the cathode at some distant point. If a faradic battery be used the same poles will be applied, and in the same manner. Indeed, in some cases, where the patient was quite susceptible to the effects of galvanism, I have had better results with the faradic applications. We get true polar effects from faradization.

I am glad to notice that many of our best electro-physicists now regard the faradic or induced current not as a to-and-fro current, as heretofore claimed, but as an interrupted induced current, with a flow in one direction only; consequently having strict polarity. That the faradic current possesses the same essential characteristics as the galvanic, only in a lesser degree, is, I think, now fully proven and accepted.

When an abscess is fully formed,—*i.e.*, when pus has collected,—an opening must be made, and the contents evacuated if possible. The

smaller the opening and accomplish this object, the better. The pus may be aspirated, if it be thin enough; the cavity washed out, filled with warm



DR. WALLING'S CARBON ELECTRODES.
(Drawn by Mrs. Walling.)

salt water, and then acted upon with the galvanic cathode. The aspirating needle may be insulated with shellac to within half an inch of its

point, and used as an electrode; or a suitable needle may be inserted. If, however, an opening of sufficient size has been made, one of the carbons figured on page 3 may be used, and the whole interior acted upon, if thought best. This application must be deferred, however, until after all acute inflammatory symptoms have subsided. For the purpose of electrolysis the galvanic current only will suffice, and the intensity of the action must be governed by the exigencies of each individual case.

We use the anode externally in the initial stage of abscess to subdue inflammation, change the chemical conditions, and prevent, if possible, by its specific action, the formation of pus. In the later stages, when the pyogenic membrane has been fully formed, it must be destroyed, either by the electrolytic action of the galvanic cathode or by other means. Especially is this to be done with old fistulous tracts, sinuses, etc. A galvanic battery capable of giving from 150 to 200 milliampères of current is necessary for such operations. A meter and a controller are also necessary, and a goodly supply of suitable electrodes. I use carbon electrodes wherever possible, preferring them on account of their cheapness, cleanliness, and ready adaptability to nearly all applications. They are easily shaped to suit the operator and the operation, and a set may be prepared for each case, if it be malignant, or for any other reason.

When the cathode only is to be used, and the carbons are not admissible, anything that will conduct the current, suitably insulated, may be inserted into the abscess, sinus, fistula, or whatever one may be dealing with. A piece of ordinary copper wire will answer, or, better still, what is known as *phosphor-bronze* wire. This I use in making all my attachments and some of my electrodes, as it is very strong, as springy as steel, while much more pliable. Double it and, except at the extreme end, treble it, twist it upon itself, and form an attachment at the other end by twisting it around the cord-tip. Insulate it with shellac or hard rubber, leaving as much of the active end exposed as may be necessary. Where insulation was not essential I have, upon occasion, used one of my silver probes as an electrode, making the attachment by passing the probe through one of the eyes in the cord-tips, and holding them together with firm pressure.

We will suppose that you are dealing with a chronic abscess, that you have aspirated it, or otherwise emptied the sac, and now wish to act upon the inner surface. Having everything in readiness, test your battery, that you may be sure which pole you introduce into the cavity. (To make this test take a piece of red litmus-paper, wet it thoroughly; place the free cord-tips on it, about half an inch or so apart, the cords being, of course, attached to the battery; turn on current enough to get a reaction. You will notice no change in color under the anode or positive, while the paper will turn blue under the cathode or negative. If you use blue litmus, the anode will become red, while there will be no change at the cathode.) We may be dealing with a chronic abscess, the

result, let us say, of spinal disease. We cannot aspirate. We must make an incision, when we will find the walls lined with a thick, caseous pus, which the ordinary surgeons remove with a Volkman spoon. We may do this, or we may at once proceed to reduce it by electrolysis, using one of my carbons for this purpose, washing out the cavity as required. Use the cathode in the cavity, with a large pad with the anode at some indifferent point. To break down caseous pus, 10 to 20 milliampères will suffice, but to destroy the thickened and indurated pyogenic membrane lining such cavities a current-strength of from 50 to 75 milliampères may be necessary. After going thoroughly over the cavity and washing it well out, dress as after any other method of treatment, and sustain the patient in every way. It will probably be necessary to use an anæsthetic during the operation. My reasons for using electrolysis in such cases are, that the galvanic current is antiseptic in its action, *per se*, and that the operation may be well and thoroughly done at one sitting, and much valuable time saved; also that a much smaller incision is necessary than under ordinary surgery.

The germicidal action of the galvanic current has been so repeatedly demonstrated, and by such able investigators, that I do not need to discuss it here, further than to say that in skin diseases of parasitic origin I have used the galvanic anode, applying mercury bichloride in this manner with the most happy results.

TUBERCULAR ABSCESS—SO-CALLED SCROFULOUS GLANDS.

The earlier these are recognized and attended to, the better. If taken in time and given appropriate attention, suppuration may be prevented, and resolution brought about by absorption. Make direct application with the cathode, unless there be acute inflammation, or you wish to introduce some medicinal substance with the anode. Use a current-strength of 5 to 10 milliampères, and do as much at each sitting as the patient's strength will allow without fatigue. The effect of the current in these cases is threefold,—the electrolytic, the interpolar, and, if applied directly into the tumor, germicidal, as before stated. We want to avoid breaking down these glands if possible. Let us dissipate the tumor and prevent further infection. After they have broken down, act upon their contents thoroughly with the cathode. The writer has had many such cases, where the gland had been opened but could not be healed. By the direct application of the galvanic cathode every other day, the gland became healthy and healed up, while other glands in the region, and on the other side of the neck, that had not yet suppurated, yielded to the outward application and the swelling disappeared.

Scrofulous children with suppurating glands of the neck have been, by such treatment, combined with judicious medication, restored to health. If the tubercular infection be confined to the exterior, the patient may be cured; and even when the lungs are invaded, there still

is hope if proper electrical treatment be added to other rational means. That tuberculosis is curable in its early stages there is no doubt.

I have not used any germicidal drugs in connection with tubercular abscess, my reliance having been placed solely upon the inherent powers of electricity itself, and I have not been disappointed. In this connection I desire to say that the static insulation and the inhalation of the great quantity of ozone generated by the static machine are of vast benefit in these cases, when the bacillus has invaded the lung-structure.

When we do not wish to aspirate,—in fact, when the gland would be better treated without any opening other than that made by the needle,—it may be treated by electrolysis only, if we may so use the term. In such a case use the cathodal needle, two or more, in the tumor, according to its size, and by gentle stimulation and electrolysis cause its absorption. Use a current-strength of 5 to 10 milliampères, with sittings as often as the condition will allow. Dress with iodoform collodion and keep the parts in as cleanly a condition as is possible. If the patient object to iodoform, use plain collodion. It contracts firmly, and hastens absorption in that way. Of course, proper medical and hygienic treatment will be given in connection with the electrical applications. It is not within the province of this work to enter into such medical treatment very fully, but I wish to say that the sulphide of arsenic is a very potent factor in such medication. In my next case I purpose trying this drug in a cataphoric way,—that is, by means of the galvanic current applied locally to the tuberculous glands,—and shall take pleasure in reporting the result.

Too much importance cannot, in the writer's estimation, be attached to the treatment by central galvanization, and to the pneumogastric nerve, in strumous, bronchial, or asthmatic affections, as well as in all diseases where there is a lowered tone of the nervous system. A most admirable method of administration is as follows: A wide bandage or belt, sufficiently long to pass twice or more around the waist of the patient, is wetted in warm water and placed in position. Over this is placed a belt of metal,—for this copper being very suitable,—to which is attached the negative pole of the galvanic battery. The positive pole has two cords, one passing to the sponge, upon which the patient may sit, or to a pan of water, in which the feet may be placed, and the other to the electrode to be applied to the neck.

A current-intensity of from 5 to 10, or even more, milliampères may be used for ten minutes, every day or every other day. At the close of the sitting change to the secondary faradic current for two or three minutes.

Treatment about the neck should include the cervical portion, and especially the pneumogastric nerves on both sides. Let the electrode rest in the angle behind the jaw for some time; also in the supra-clavicular space. Marked improvement in tuberculous cases will manifest

itself in a short time. I sometimes modify this treatment as shown on page 26, as that is applicable in many cases where the foregoing is not. The water used should always be as warm as can well be borne, and the room should be at a temperature of not less than 75° F. Treatments may be given when convenient, but the better time is during the day, rather than at bed-time.

If the patient be unable to visit the office, perhaps is confined to the bed, arrange as follows: Place a large pad on the stomach and abdomen (cathode, as before) and place a long pad on the cervical and dorsal region (anode), or encircle the neck with a suitable bandage with a flexible copper or other plate for the current, and proceed as above. A plate may or may not be placed at the feet. The main object to be attained is to bring the pneumogastric nerve under the direct action of the current. Sometimes a tongue-plate may be used. Treatments should be persisted in for a long time, even after the patient feels well.

Adenomas—Glandular Tumors.

These appear only in pre-existing glandular tissue. Pure adenomas are rare, the adenoma-fibroma or adenoma-myxoma being more often seen. Frequently the acini or ducts in the adenoma become dilated into cysts, in which proliferating growths may project. They are then termed adenoma-cystoma or adenoma-sarcoma, according to the interlobular or interacinous connective tissue. Both these varieties are differentiated from a true sarcoma, in that the epithelium does not penetrate the basement membrane and invade the connective tissue. For this reason such tumors are called benign, in that they may not return after excision or destruction. They may, however, undergo secondary degeneration, consequent upon mucoid softening and fatty degeneration of the epithelium. The writer regards every such tumor with suspicion. They all belong to the same family, and any one of them may be the black sheep of the flock. Who shall say where the line of differentiation is to be drawn, when we find so many apparently benign growths degenerate into malignancy? Consequently, I have come to regard all tumors, of whatever sort, with a certain degree of suspicion.

The tubular variety resembles the tubular glands, occurring mostly in the intestines, where they form polypoid growths. They are occasionally seen in the rectum. They are the occasion, in some cases, of hæmorrhages from the bowel in children. They are easily detected, and may be readily removed with the cautery-loop or snare.

Treatment of Adenomas—Adenoma-Fibroma of the Thyroid, or Goitre.—Extirpation is not considered advisable, as the removal of this gland seems to be attended with danger. Electrical treatment may be given in three ways: direct galvanization by means of large electrodes applied on either side of the tumor, using a current-strength of 5 to 15 milliampères, or the cathode may be placed on the tumor and the anode

in the auriculo-maxillary angle, using the same current as above; by galvano-puncture, or electrolysis; and by cautery puncture.

The first method is the one generally used, with sittings of from five to ten minutes, given as frequently as the irritation caused by the current will permit. A solution of the iodide of potassium applied by means of the *cathode* should be of decided benefit. Some operators have used the tincture of iodine on the anode, claiming good results thereby. Iodine is always an electro-negative body, and will be very readily introduced into the system by using it on the cathode.[1]

I take occasion here to remark that I was the first to call attention to the relation of the chemistry of the poles of a galvanic series to the substances to be used with them, pointing out that, with such substances as sulphate of morphine, aconitine, and substances where the base was to be introduced into the system, the anode should be used; but when it was desired to introduce the substance that took the place of an acid, as the iodine does in the iodide of potassium, the cathode should be used. The acids, and all bodies that take the place of an acid in forming salts, are electro-negative bodies, while the bases are electro-positive bodies, and consequently are repelled by negative and positive poles, respectively. The use of electro-negative substances with the positive pole of the battery is contrary to the law of electrical affinities.

Electrolysis in the Treatment of Goitre.—This method is both safe and rational. Both poles may be inserted into the tumor, using platinum or gold needles with the anode; but I prefer the cathode only, and I think this is the plan pursued by most operators. The sets of needles I use were made for me by Mr. Otto Fleming, of Philadelphia, after patterns furnished by myself. There are two sets, one of steel and one of platinum. The steel needles are what are called embroidery needles, and are each mounted in a heavy cord-tip, to which the conducting cable is attached, four needles being in each set. The insulation is shellac, and to within three-eighths of an inch of the end.

In operating on a goitre the parts are washed and, if need be, injected with cocaine. It is better to do this, in some cases. Having everything in readiness, place a large anodal pad on the shoulder, or near by, and thrust one or more needles boldly into the tumor, until the insulation is beneath the skin. Gently turn on the current until you get 5, 10, or even more milliampères, let it run for from two to five minutes, and the operation is over for that time. The cathodal needles must be held in place, or their weight will cause them to fall out. If the tumor be very dense and unyielding, and it be difficult to introduce the needles, push them through the skin, turn on the current, and then press them in as far as you wish. The electrolytic action enables you to insert them as far as is desirable. Repeat the operation in from five to seven days,

[1] See a paper by the author, read before the American Electro-Therapeutic Association, on the chemistry of cataphoresis, October 4, 1892.

but in another place. Using several needles at once will, in some cases, be better. The operation is entirely without danger, and causes but little pain. Dr. Hutchinson advocates the use of long, fine, uninsulated needles in his treatment of fibroids by abdominal puncture. He states that the current will follow the needles and not act upon the skin; but, as action takes place wherever there is contact, it would seem to be better to use insulated instruments.

How does the current affect the tissues so as to bring about a cure? "All the tissues of the body have their origin in the primitive material which we term protoplasm. This protoplasm has certain movements which characterize its life, and these movements are affected by mechanical, chemical, and electrical energy, differing in character,—that by slight excitation by the induced or faradic current increasing the rapidity of the movements, stronger ones causing tetanic contractions, and numerous and powerful ones causing coagulation.

"The galvanic current causes dilatation and contraction of the blood-vessels by direct stimulation of their muscular fibres, acting in like manner upon the lymphatics, causing more ready circulation of the blood and nutritive fluids; increased power of imbibition of the tissues; increased osmotic processes; changes in the disassimilation and nutrition of the nerves, on account of their stimulation or sedation; changes in the molecular arrangement of the tissues, caused by electrolytic processes; and, finally, the consequences of the mechanical transport of fluids from one pole to another." (Erb.)

The current also exerts a more or less direct influence upon the trophic centres in the anterior cornua of the spinal cord. Very powerful currents, as from a heavy dynamo, disintegrate the red blood-corpuscles immediately, causing instant death. The interpolar effects have been studied from two points. Dr. Inglis Parsons and others, acting upon fibroid tumors and other animal tissue, after removal from the body, detected no change in the interpolar region. Dr. Buckmaster, of this country, however, clearly proved that there was absolute disintegration of the living cells, by the interpolar action of a very strong current. He experimented upon the heart of a live but anæsthetized dog, showing clearly the difference in result when acting with the current upon the dead or living cell.

Having seen how electricity affects the living organism, we may readily understand how it assists nature in throwing off disease. We may also learn the lesson that it is not the powerful current or the great shock to the system that is, as a rule, needed to aid nature, but rather the mild and helpful stimulation derived from a moderate use of this powerful agent. It is for the reasons and conclusions set forth above, as to the effects of electrical currents upon the living tissues, that I advocate mild currents in the treatment of diseased conditions, and my experience confirms the deductions.

Multiple puncture with the galvano-cautery has been recommended in the treatment of goitre. I have never tried it in this affection; the resulting scars, especially in this region, would be against its use. From 15 per cent. to 25 per cent. of adenoma-fibromas of the thyroid have been reported as being cured. Some operators use both poles in the tumor. If both are used, the anode being of platinum or gold, at the close of the operation the cathodal needles must be withdrawn first, disengaged, the cord attached to a pad, which should be placed on the skin, and the current reversed and let run for one or two minutes, to disengage the platinum needles; otherwise, by forcibly removing them, bleeding may result. This will be more fully explained under "Aneurism."

The treatment of the cystic variety (in the ovaries) of adenoma-fibroma belongs to another section, and will not be considered here, further than to state that the writer sees no reason why such growths should not be successfully acted upon by electrolysis. Hypertrophy of the prostate, which is generally an adenoma-fibroma, belongs to another section, to which the reader is referred. Adenoma of the lip, or of a sebaceous gland, is to be treated by negative electrolysis, as in goitre.

If any of these tumors become cystic, the contents are to be evacuated in the best manner, and the cysts destroyed by galvano-cauterization, or by acting upon the contents before evacuation, as the writer does in hydrocele, and absorption brought about in that manner. This may be done in two ways. I use a trocar and cannula, the cannula being insulated; thrust this boldly into the tumor, and, if desired, draw off some of the contents. Replace the trocar, keeping the cannula *in situ.* Have a connecting tip on the cannula, into which the cord-tip may be pushed. Apply the anodal pad on some convenient point and turn on the current. From 20 to 30, or even more, milliampères may be used and run for ten or fifteen minutes. There will be distension of the sac, by reason of the liberation of hydrogen-gas, by electrolysis. Allowance must be made for this if the sac be very full, by previously drawing off some of the fluid, as before stated. The second method is to draw off all of the fluid that is possible, insert a somewhat blunt electrode, and cauterize the whole of the inner surface if possible, using a current as strong as the patient will bear,—say, 15 to 25 or more milliampères. This application must be rapidly made, as it is painful. Possibly a solution of cocaine might be placed in the cavity, but there might be too much introduced into the system and affect the patient seriously. Where the cavity will admit, use one of the small carbons shown on page 3. These carbons are easily sterilized by passing them through an alcohol-flame, after being washed. The thorough cauterization of all pyogenic and cystic membrane will go far toward promoting a rapid and permanent cure, where such is possible.

Should there be malignant degeneration, the patient must be put under an anæsthetic and the parts thorougly and freely acted upon with

a current of 75 or more milliampères, or the cautery-knife applied until every vestige of growth is burned off. Do not spare the adjacent tissue, unless you are working on or about the face or neck. Even here it is better to do too much than too little. Do not sacrifice a life to prevent a scar.

The writer has been frequently asked if an ordinary sebaceous tumor, or *wen*, as such is commonly called, could be removed by electrolysis. It could be cauterized out, but the better plan is to open freely, turn out the whole thing, sac and all, as is ordinarily done. I never touch such a tumor with electricity unless malignant degeneration has taken place. We want to bring about a removal or cure of every lesion, in the easiest, quickest, safest, and most rational manner. If ordinary surgery be the better method, use it. If the electrical current, in some one of its forms, offer the best method, use it. We should be wedded to no single method or system.

Adenoma-fibroma of the parotid may be treated in much the same manner as in ordinary goitre, only greater care must be exercised in placing the needles. The close proximity of the great blood-vessels renders this region difficult to treat. The positive current causes a contraction of the walls of the blood-vessels, lessens the flow, and causes vertigo. While this may not be alarming, it is unpleasant, especially to the patient who is in a condition to note all untoward symptoms. Better to gently warn such patients just what to expect, and the result will be more favorable. I think it better, in most of these cases, to make cathodal applications to the gland, with the anode on the nape of the neck. You may then gradually increase the current to the point of tolerance without disturbance. When you are through and wish to turn off the current, do so slowly and gently, as a sudden withdrawal produces vertigo. Avoid, if possible, in all kinds of treatment, any disturbance of the system tending to shock it.

Adenoma-Fibroma of the Breast.—The treatment for a fibrous growth in this locality will be the same as that already laid down for such tumors. If it degenerate, as it is very apt to do, into an adenoma-sarcoma, and become threatening, if surgical interference be not deemed best, the shock method of Dr. Inglis Parsons may be used with good effect. I have used this method in cancerous growths, with encouraging results. The technique is as follows: Required, a battery sufficient to give 500 or more milliampères; a controller that will *control*, and two gangs of needles, four to six in each gang. One gang, that for the anode, must be of gold or platinum. The patient must be under the influence of ether, or the A. C. E. mixture. Thrust the needles well into the base of the tumor, the anodal on one side and the cathodal on the opposite, and let the ends of the needles, as they are buried in the tumor, be from one-half to an inch or more apart, according to the size of the growth. If it be small, four needles, two on each side, will be sufficient. Every-

thing being in readiness, the needles in position, and the cathodal needles held in position by the assistant, turn on the current quickly, until the meter shows 500 or 600 milliampères. The electrolytic action with such a current is rapid and powerful, and you must work rapidly. As soon as you get the desired ampèrage, break the current by removing one of the cord-tips, and tap the binding-post with it, thus sending a series of powerful shocks through the tumor. Another good method is by voltaic alternatives; that is, by sudden reversals of the current by means of the pole-changer. These shocks may be repeated half a dozen times or more, carefully watching the patient meantime, to note any signs of overstimulation or heart-trouble. The current must not be allowed to *run* uninterruptedly for more than five to ten seconds at a time, or, the action being too great, a heavy slough will result. The writer had this to occur in one case, and recognizes the danger from such powerful currents when localized.

If properly and skillfully done, the tumor will gradually shrink and dry up, as it were, becoming finally almost entirely obliterated. This method need not be confined to malignant growths of the breast, but is applicable to parts remote from the nervous centres, or the heart; although Dr. Parsons operated in the left breast and axilla successfully, and without fatal result. Great care must be exercised, however, in using such currents near the heart.

Adipose Tumors—Lipomas.

These are considered benign tumors. They are most commonly found on the shoulders, back, nates, etc., and may be due to pressure from some cause. The secondary changes which are liable to occur in these tumors are calcification, mucoid softening, inflammation, and adhesion from pressure. I have never attempted electrical treatment for this class of tumors, except incidentally in giving general treatment. They are so very easily removed with the knife that surgical interference would seem to be the rational procedure. If, however, they become inflamed and painful, anodal applications with a soft, smooth, faradic battery may be given, or the same pole of the galvanic, with cocaine or morphine to allay pain.

Electrolysis has been used in this class of tumors, but it does not commend itself to my judgment, and I have refused to attempt it. Where so much is to be gained by ordinary surgical methods, it will be a waste of time to attempt the reduction of a lipoma with electricity.

Aneurisms.

Classification.—Aneurisms may be divided into the fusiform, the sacculated, and the dissecting. (See the text-books.) These distinctions must be borne in mind in diagnosing an aneurism, and as a guide in the treatment.

Treatment.—Obviously, an aneurism of the aorta, or in the iliac or

femoral arteries, is much more serious than in smaller vessels, and for the reasons given under "Classification." The location and probable extent should guide us in the treatment. An aneurism of the ascending aorta, for example, could only be reached and treated through the chest-walls. Electrolysis offers the only surgical relief. In acting upon the blood-stream in this class of tumors, only the galvanic anode should be used in the tumor.

We will suppose that we have to deal with an aneurism in the popliteal space, which is a frequent seat of these tumors. It must be differentiated from malignant disease of the bone, or an affection of the joint, —not a difficult matter, unless it has become diffused or has broken down, when amputation may be necessary. Having diagnosed the tumor as an aneurism, the patient will be laid prone and the limb elevated as much as possible. The battery being in readiness, apply the cathode to the limb, or at some convenient place; cleanse the space; have an assistant make firm pressure on the artery, both above and below the tumor; thrust three or four of the platinum needles boldly into the tumor; turn on a current of from 20 to 30 milliampères, and let it run for fifteen to twenty minutes, or longer if necessary. Take plenty of time. Let the tumor feel solid before removing the needles. If your insulation be perfect there will be but little discomfort; so do not hurry. When the clot has fully formed, turn off the current; reverse the poles by means of the pole-changer on the battery; then again turn on the current for one or more minutes, or until the needles may be readily removed. The reason for this reversal is, that the clot formed by the anode is very dense and firm, the needles are firmly imbedded in it, and, if forcibly removed, bleeding will follow. By reversing the current-flow and having the negative current on the needles, the clot immediately on them will be electrolyzed off, and they will become free.

Before attempting any such operation, the beginner should practice with the needles in freshly-drawn blood, in egg-albumen, and in other coagulable substances, in order to familiarize himself with the different actions of the two poles. The coagula at the cathode will appear frothy, be full of bubbles of hydrogen, easily broken down and loosened; while that at the anode will be firm, adherent, and hold well together. For this reason, the anode is preferred for aneurismal operations.

It is not necessary to make the pressure, before directed; only, if properly done, it will facilitate the operation. The sac must be kept full. If the pressure be uneven this may not be done, when it will be better to dispense with it. There is little danger of embolism where the anode is used, and the treatment on an aneurismal tumor, wherever found, if amenable to the electrical current, will be practically that just laid down. The larger the sac, the longer it will take to form a clot sufficient to close, or nearly close, the enlargement.

Only an experienced operator should attempt galvano-puncture for

an aneurism of the aorta, or for such a lesion in the large abdominal vessels. Axillary aneurism, if not diffused, will be treated in the same way. Indeed, for all ordinary lesions of this character, galvano-puncture is the ideal method of treatment.

Varicose veins may be considered in this connection, as being germane to the subject. They may be acted upon in the same manner as for an aneurism of an artery, and the vein obliterated. The anode must be used as above indicated, and for the same reasons. If the tumor be small, let the needles be insulated to within an eighth of an inch of the end, and use but one at a time, using 10 to 20 milliampères of current, and reverse the current at the close, as above directed.

Before the galvanic current was used for the treatment of varicosities, the static spark was successfully applied. At least, cases of such cures were reported in the old country.

Callosities.

CORNS, BUNIONS, ENLARGED JOINTS, ETC.

Corns.—These may be treated with the static spark, or, if very sore and painful, with the galvanic anode and cocaine.

Place the foot on a wet foot-plate attached to the cathode, and apply the solution of cocaine to the inflamed spot on the anode, using 2, 3, or possibly 5 milliampères for five or more minutes at a sitting. If an abscess has formed, treat it as the case may demand, but electrical applications will promote rapid healing. Pressure must, in all cases, be removed.

Bunions.—These painful enlargements are amenable to both the static spark and galvanic applications with cocaine. If simply painful, a fine static spark drawn through the shoe will suffice. Treat for five or ten minutes. If very sore, as well as painful, make the anodal-cocaine application, as above. Pressure must, of course, be removed. In making the static application a point in the centre of the bunion will be found to be anæsthetic. Continue the sparks at this point until the patient states that the current is felt, when the sitting may close for the time. Insulation is not necessary in these cases. I have generally used the anodal spark in these affections, but am not sure that it makes much difference which pole of the static machine be used. It seems to be the rapidity of the vibrations that relieves the condition; therefore let the machine be run rapidly.

Enlarged or Gouty Joints; Gouty Deposits.—The writer has not met with the success desired in the treatment of these affections. The static spark has been used, and the lithium salts with the galvanic current, but so far with little appreciable effect. Sufficient current could not be borne, in the cases where galvanism was used, to produce any result at all satisfactory. Perhaps the sittings (half an hour) were not long

enough; but the patients get tired in that length of time. However, I shall repeat my experiments, with, I trust, better success.

The technique is as follows: If the joints of the hand be affected, place the member in a saturated solution of lithium citrate or carbonate, connected with the galvanic anode. Place the other hand, or the foot, in a vessel of salt water, to which is attached the cathode. Turn on all the current the patient will bear, and let run for from one-half hour to three or four hours, provided the patient will submit. In making such applications, the point of greatest discomfort is at the edge of the water; hence I wet a bandage and carry it up the arm or limb from beneath the water, which diffuses the current and prevents discomfort. Longer sittings may be had in this manner. I take this precaution in all cases where immersion of any part is desired, in connection with electrical applications.

Hæmorrhoids—Piles.

If the pile be external and a clot has formed, the tumor must be opened and the clot turned out. If of recent date, and the clot not formed, a small needle, connected with the galvanic anode, may be thrust into the centre and a current of 5 to 10 milliampères used for three to five or more minutes, or until the tumor is hard. This clot may then be turned out, or left to nature. The internal tumors may be treated in the same way.

I have successfully applied the galvano-cautery to hæmorrhoids. Use a small platinum knife, and make light, quick touches to the tumor. Do not have too hot a knife, and do not burn through the coats of the tumor, or a hæmorrhage will result. The multiple applications shrivel up the pile, and it disappears.

If the anodal needle be used, care must be had at the close of the operation. After the clot has fully formed, reverse the current for half a minute or more, as in other needle operations, before attempting to remove it. This operation is painful. The parts are sensitive, tender, and easily hurt. Some enthusiastic operators have abandoned galvano-puncture in these affections, because of the intense discomfort. The inflammation resulting from the puncture, if of consequence, is to be treated on general principles. In all these delicate operations it is necessary to use a rheostat, or current-controller, as the addition of cell by cell causes more pain, as each cell gives a little shock. Then, too, the current is not so readily or easily increased or reduced as with a controller. Some authors recommend direct faradization to the pile-tumors. This method has not been successful in my hands. A little caution is necessary when working in this region with electricity, as the stimulation sometimes causes an uncontrollable desire to defecate, which might be unpleasant to both operator and patient. Previous to all rectal operations of any kind, see that the bowel is entirely empty.

While, as already stated, electro-puncture is painful, it is absolutely safe and free from danger, which is more than can be said for carbolic acid and other substances which are injected into these tumors. As for asepsis, the current itself is highly antiseptic, even if no other precaution be taken. Germs, even if introduced on the electrolytic needle, are soon destroyed by the current.

Torticollis.

This affection, if of long standing or congenital, gives negative results, as a rule. It partakes of the nature of a paresis and a spasm. If the latter element predominate, electrical treatment will be of great benefit. "The affection has its real seat in the spinal accessory nerve, or in those motor filaments that innervate the sterno-cleido-mastoid and trapezius muscles. The evidence of irritation of a motor nerve is spasm of the muscles to which the nerve is distributed." (Bartholow.)

The affected muscles are very tense, rigid, and painful. The opposite or antagonistic muscles are correspondingly weak and relaxed. The object of our treatment will then be the toning up of the weak muscles and toning down the contracted ones. The flabby ones are to be roused to action by the faradic current, causing sharp contractions for three to five minutes; but do not tire the muscle. The primary current from the faradic coil will be the one to use. Pull the plunger or cylinder that regulates the current entirely out, thus getting the full force of the primary coil. Control the current with your rheostat. An interrupting handle will be the most convenient, if there be no automatic interrupter on the battery. The indifferent pole may be placed on the shoulder or held in the hand. A small electrode is to be used on the muscle and the motor points quickly and repeatedly acted upon. Electro-massage is also good treatment, especially for the rigid muscles on the other side. As before stated, the contractions must not be carried to the point of fatigue. If you have no controller, use, of course, only so much current as will give a sharp, quick contraction of the muscle. For the tense and contracted muscle we will use the galvanic cathodal applications, as we want the relaxing effect of the negative current. The faradic cathode has the same effect, but in a much less degree. Apply the anode to some distant point, if convenient, and go over the rigid muscles with the other pole. I sometimes use a roller electrode, in such conditions, with good effect.

We must not expect too much from our treatment. If the case be one of long standing, there has some change taken place, probably, in the nerve supplying the muscles, and such degeneration cannot be restored. If the torticollis be recent, or of rheumatic origin, we may expect good results. In addition to the local treatment, pass a gentle current through the base of the brain and the medulla, by placing the sponges on either side of the head, back of the ears, and then a little

farther back and down, so as to reach the medulla as nearly as possible. Use a current of 2 to 3 milliampères. If vertigo be caused, lessen the flow and continue the application for two or three minutes. In using electricity on the neck, especially on the sides, over the great blood-vessels, vertigo will be readily produced, in many cases, when the current affects the blood-vessels directly, especially if the anode be used.

The static spark is of use in torticollis, applied to the weak side. Some authorities recommend strong currents in this affection, but I prefer milder measures. It is very easy to overdo the matter when making electrical applications. The patient is anxious for recovery; the doctor wishes to make a favorable impression, and frequently yields to the request to put it on stronger, often to the damage of the case. There are cases, of course, where high voltage and ampèrage is necessary; but they have been rare in my practice. With the exception of the shock method in the treatment of cancer, I have never exceeded 125 milliampères in any application, and generally the ampèrage has been from 50 to 75 milliampères, or less.

There is one error, however, that I wish to combat, and that is the statement made by some writers, that a feeble current, long continued, has the same effect as the same amount of electricity applied in a short time. This, in the very nature of things, cannot be so. When necessary, use heavy currents, but be very sure that they are necessary before doing so. Great and irreparable injury is often done to an injured or enfeebled nerve by a powerful current of electricity. Especially is this the case when dealing with paretic or paralyzed muscles. I notice this broad and general statement going the rounds of the medical press: that the rule in treating any paralysis is to use the current that will give the strongest contraction. Now, we do not want to produce contractions always, and in every treatment of any case. We must treat each case individually, and not from such very broad premises. As before stated, it is absolutely essential that the muscles be not fatigued. In torticollis and allied affections this may very easily be done; hence I again call attention to the matter, and warn against overdoing. Better a two-minute treatment, repeated twice in each twenty-four hours, than half an hour's application every second or third day. As the muscles become stronger, more vigorous treatment may be given. If the spinal cord be involved, or there be a central complication, regular brain and spinal applications must be made; but there will be, as a rule, little progress made. I may conclude this subject by saying that I class all spasms and very recent contractions of muscles as being electro-positive in character; hence should be treated with the anode. All old contractions, such as a torticollis of long standing, are electro-negative in character, and are to be treated with the cathode. This is a principle in electro-therapeutics that is, to my mind, thoroughly settled. The same rule applies in many other diseases, but not all chronic lesions are

electro-negative. In some the electro-positive element still predominates, such as excessive irritability in the nerves, in some old spinal affections.

Specific and Malignant Diseases of the Rectum.

SPECIFIC OR SYPHILITIC DISEASES.

These require protracted constitutional treatment, which will not be considered here. Stricture of the rectum is one of the common sequelæ of syphilitic ulceration. It may also follow any severe inflammation of the part, due to fibroid contraction of inflammatory products in the mucous and submucous coats, or of cicatrices following simple or dysenteric ulceration, and injury to or operations on the bowel. The treatment of the simple structure will not be here considered.

Syphilitic Ulcers of the Rectum.—These must be located and acted upon directly with a zinc electrode, using the positive pole for its escharotic effect. Caution is here necessary, as we must be careful not to overdo. It may be necessary to divulse the sphincter before proceeding to operate. Use a hard-rubber speculum, and act only on the affected portion with the current. Wash out the bowel thoroughly before commencing with the electrical treatment. Observe what has been said previously regarding this procedure.

In making applications to these inner mucous surfaces, small electrodes are necessary. If zinc is not convenient, use a carbon; when the cathode will be preferable, unless there be much bleeding; if so, the anode must be used. Place the indifferent pole on the buttocks or thigh, and use a current of 5 or more milliampères, as the patient can bear. Weak currents and longer applications will bring about healthy granulations, provided the constitutional treatment be satisfactory. If there be much pain and soreness, use the anode and apply cocaine. It may be necessary, in some cases, to use a strong current and cauterize the parts freely. This, however, can better be done with the cautery-knife, and much more rapidly. If the diseased portion be extensive and a severe application be necessary, the patient must be placed under ether. The sphincter may then be put upon the stretch, paralyzed, and the operation much more satisfactorily done. Of course, thorough surgical methods must prevail.

FISTULOUS TRACTS AND SINUSES.

These frequently result from severe ulceration. The proper treatment is to act upon the whole tract with the galvanic cathode, using a small electrode, insulated to within a half-inch or so of the active end. A good-sized wire may be used. Insert it, turn on from 10 to 20, or even more, milliampères of current, and act upon the whole extent, if not too long. If the sinus terminate in an abscess, as is frequently the case, this must be found and evacuated, and its cavity treated as laid

down under "Abscess." If the sinus be long, only a part, and that the most inner portion, should be cauterized at a sitting. Allow that part to heal before attempting to close below it, or an abscess will form and more trouble be experienced. If the fistula be complete and open into the bowel, find the inner opening, pass the electrode up through this inner opening, if possible, and close it by setting up adhesive inflammation. The anode will be preferable for this. Great care must be exercised, however, or you will find the electrode immovably fixed *in situ.* If you cannot close the upper portion, do not attempt to do so with the lower. Work from above downward always. It will not be necessary to wash out the tract when using electricity.

FISSURES IN ANO.

These troublesome and sometimes intractable little lesions are very readily and easily treated with negative galvanic applications. Sometimes one treatment will obliterate a fissure. Dilatation of the sphincter is not necessary, unless the fissure be very extensive. If it be so, and the muscle is divulsed, the treatment to be laid down will be all the more effective.

Wash the parts if necessary. Apply the anode to the thigh, and with a suitable electrode—a small carbon being preferable—act upon the whole surface of the fissure with the cathode, using a current-strength of 5 or not over 10 milliampères. Repeat the operation as soon as the inflammation incident upon the application has subsided,—provided, of course, that such repetition be necessary. Every part of the diseased surface must receive attention, and the work thoroughly done. One case that came to the writer was that of a gentleman from Washington, D. C., complaining of an annoying fissure, saying that he could not spare the time for regular surgical treatment, which consists in divulsing the sphincter, etc. A five-minute application of 5 milliampères of current, with the galvanic cathode, using a silver probe as an electrode, completely relieved him. Upon his next visit, two weeks after, I found the fissure healed.

The effect of the current in such cases is first to destroy the outer surface of the fissure, sear over such surface,—thus protecting it,—and stimulate the granulation to healthy action. In making such applications to lesions of this character and those just previously considered, we must, if using rather strong currents, give ample time for the parts to heal, after one operation, before attempting another. If this precaution be not observed, and the parts but partially healed, the electrolytic effects of the current will remove the partially-formed new and healthy granulations, and the healing process is retarded. The same precaution is to be observed when the cautery is used in this locality. A week or ten days, or even two weeks, had better be allowed between treatments than a shorter period. We cannot hasten, beyond a certain limit, the restorative processes of nature. We may do much to hinder. In some

of these cases a single treatment will suffice, as in the one referred to above. Had the patient received such an application every day, the fissure would not only not have been healed, but it would have grown worse and worse with each frequent disturbance of the healing process.

MALIGNANT STRUCTURE OF THE RECTUM—CANCER.

Pathology.—Cancer, in all its forms, may occur in the rectum, but the variety of epithelioma known as the columnar, or adenoid, is the most common. It occurs as either a fungating, more or less distinct tumor, projecting into the lumen of the bowel, or as a laminar, nodular, or ring-like infiltration of its coats. In either case, it is at first covered by apparently unaltered mucous membrane, which sooner or later is destroyed by ulceration, leaving an ulcer with an uneven, proliferating, or excavated surface, everted edge, and indurated base. As the disease extends it involves the muscular coat and, subsequently, the surrounding structures and organs, gluing them as it were to the rectum, and finally converting the whole into a cancerous mass. The lymphatic glands in the pelvis and, later, the inguinal glands and others more remote, become affected, and the carcinoma may finally be disseminated, secondary growths being more especially met with in the liver.

The *symptoms* are often very insidious. At first there may merely be some uneasiness, hardly amounting to pain, about the anus; then more or less pain on defecation is noticed; the fæces may be streaked with mucus or blood, and a slimy discharge may be present. Later, the motions become small, flattened, pipe-like, or scybalous. The patient strains severely at stool, and says he feels as if the bowel had not been emptied; then there is constipation, alternating with diarrhœa, and an offensive, sanious discharge. Emaciation and cachexia now appear, with more local pain; and the patient dies of exhaustion, peritonitis, or during an attack of acute obstruction of the bowels.

The *diagnosis* can only be made by careful local examination. The anus generally appears healthy, though it may be patulous, and a healthy strip of mucous membrane generally exists between the anus and the growth. When the growth can be felt by its indurated base, and when ulceration has occurred, the everted edges of the ulcer and the foul discharge render the diagnosis easy.

The fungating form may be mistaken for a villous growth; the annular for a simple fibrous stricture. A villous growth may be distinguished by its velvety and supple feel, by its not ulcerating or breaking down, by the absence of induration, by the discharge being thin and mucoid and the rectum not fixed, and by the duration of the disease. A fibrous stricture may be known by its longer duration, by being less indurated than the cancerous form, by the bowel not being fixed, and, when due to syphilis, by the absence of a healthy strip of mucous membrane between the anus and the growth.

Treatment.—If seen and recognized in the early stages of the disease, and before the surrounding parts have become seriously involved, and the growth be not too high up in the rectum, much may be done to relieve if not to entirely cure. The growth, with the infiltrated tissues as far as possible, must be acted upon with the metal anodal electrode, and all diseased portions removed. The patient must be under the influence of an anæsthetic. Apply the indifferent electrode to the thigh, the abdomen, or back, using a large pad. Divulse the sphincter, bring the growth into view with a volsellum forceps, and remove, by electrolysis and cauterization, all or as much of the diseased tissue as is possible. This may not be attempted at the first operation, as it might involve too much subsequent inflammatory reaction. Use a current-strength of 75 to 100 milliampères, and work as rapidly as possible. The anode will be preferable here, on account of its hæmostatic effects. Very little blood will be lost. Repeat the operation if necessary, after the parts have sufficiently healed to permit. Meantime, the bowels are to be confined, especially for the first few days.

The effect of the electrical current, especially the galvanic, upon such growths is germicidal as well as electrolytic. The low form of cell-life in these cancerous tissues cannot resist the destructive influence of electricity: even when the electrode does not come in actual contact with them the interpolar action goes on with certainty. Needles are sometimes recommended, instead of zinc electrodes; but the needles are too small and the action too slow. The quicker we remove the offending and offensive growth, the better. For this purpose Byrne, of Brooklyn, uses the cautery-knife and loop. This is most excellent treatment, but requires more skill than the other. It is very effectual when properly done. It is much more rapid also, and the mass may be completely cleaned off at one sitting.

How does such an operation compare with excision by ordinary surgical means? Without entering into a lengthy discussion regarding it, I will say that, considering what has already been said regarding the germicidal action of the galvanic current, or the effects of the cautery heat upon the low order of life in these growths, it would seem that the balance would be in favor of electricity. Furthermore, that such growths in other locations have been successfully treated by electrolysis, saying nothing about the shock method of Dr. Parsons as added evidence in its favor.

If syphilitic growths are found about the anus, they may be readily and easily removed either by the use of the needles or the cautery-loop. Should the epithelioma occupy this region, as I have seen, though rare, it too may be removed in the same way. Villous tumors, papillomas, and in fact any and all tumors incident to this locality, may be acted upon in the same way. If the pedicle be small, the cautery-loop will serve the better purpose. In operating with this instrument care must be had not

to have the wire too hot. If too great a heat be used, the tissues are burned through too quickly; the mouths of the blood-vessels are not sufficiently closed, and secondary hæmorrhage is apt to result. The same precaution is to be observed in all operations with the hot platinum wire. If an ordinary cautery battery be used, see that everything is in perfect working-order,—good fluid, clean plates, close and proper connections, and of easy manipulation. Test the degree of heat and notice how deeply the plates are immersed to produce a heat above a dull red. Bear in mind that it will require somewhat more current to produce the same heat in the wire when buried in the tissues, and regulate it accordingly. We will suppose that you wish to remove a growth the size of an ordinary orange, with a pedicle somewhat smaller than the tumor. See that everything is in perfect readiness, as above directed. Pass the loop around the growth, the patient being, of course, under the influence of an anæsthetic; draw the loop closely to the skin, immerse the plates slowly until the wire is sufficiently heated just hot enough to burn its way slowly through the tumor, and gradually tighten the wire as you proceed. As the wire becomes fully imbedded more current will be necessary. This must be learned by experience. If the tumor be large the wire may be passed through the centre of the pedicle by means of a suture-needle, and one-half operated upon at a time. If the tumor be malignant it will be better to cauterize the seat of the growth after removal. Leave no diseased tissue or suspected portions untouched by the cautery. Do it thoroughly and well. Dress the wound as in ordinary surgery, and watch for further developments. It will be better for those unused to operating with the cautery to become proficient in its use by experimenting upon the cadaver; upon anæsthetized animals, which must be killed immediately if much be done, or with pieces of raw beef or other animal tissue. More will be learned in a few hours experimentation in this way than by studying the books by the month.

If the needle-operation be preferred in any of these cases, it will be performed as follows: Have the battery, meter, controller, indifferent electrode, and needles all in perfect order by previous testing. If a small tumor is to be acted upon, and without the shock method, no anæsthetic will be necessary, unless cocaine be injected. Place the indifferent electrode in its convenient position,—in this case, we will suppose it to be the anode; thrust two or more needles, connected with the cathode, into the tumor at its base, and just above the healthy skin; transfix the tumor, if possible,—that is, pass the needles entirely through it; the action will be more effectual. The needles may be one-fourth to one-half inch apart, one-fourth inch being better. Turn on the current, carrying it up to 15 or 20 milliampères, and let it run for ten minutes. Turn it off, remove the needles and re-insert them in a new place, and repeat the operation in the same way. Again reduce the current; pass

the needles through the growth at right angles to their former position, and again repeat; re-inserting them once again, if need be. If the tumor be very vascular, the anode must be used in the tumor, and the current must be reversed before attempting to remove the needles. With the cathodal needles no reversal is necessary.

Dress with iodoform collodion, and in a few days the tumor will either drop off or be easily removed, having become a blackened mass of dead tissue. It may not be advisable to act so freely upon the growth at one sitting. Sometimes it will be better, as causing less discomfort, to make but two insertions at the first sitting, and repeat in one week. The resulting inflammation will be less, but, where time is an important element, do the work thoroughly at once.

There is one element that especially commends this method of operating upon growths of any kind, and that is the immunity from erysipelas as a result of the wound. I never knew it to follow such an operation on any part of the body. No especial care is necessary, as in ordinary surgery. The parts may or may not be washed previously, just as may be convenient. The current is sufficiently antiseptic to take the place of such precautions in ordinary methods.

After the growth has been taken off, go over the seat of the tumor, remove any protuberances that may have escaped action, doing this with a cathodal needle, and finally cauterize the seat of the tumor thoroughly, by means of one of the carbons shown on page 3. Use the wedge-shaped instrument, and act upon the whole surface until satisfied, as far as is possible, that all affected cells have been freely cauterized, provided you have been operating upon a malignant tumor, or one suspected to be such. Dress with iodoform collodion, and put the parts at rest. Little or no attention is necessary, as a rule, after such operations. Let nature take care of the healing process. If the tissues are in a fairly healthy condition, this will soon take place.

Some authors have made the statement that sloughs produced by the strong electrolytic or cauterizing galvanic current were very difficult to heal. I have not found such to be the case in my practice. In fact, such wounds sometimes heal very rapidly. At the same time, I would not produce such a slough unless it were necessary, just as I would not make a wound with a knife without proper cause. Another question that ought to receive some attention is the statement frequently made that electrical applications hasten the growth of a cancer, and should, consequently, not be made. If the ordinary mild faradic or galvanic treatment be here meant, I fully agree with such statement. Use strong currents in such cases,—*i.e.*, as has been pointed out in these pages,—but do not temporize. Timid applications but stimulate to greater activity. If electricity be used, let it be the master of the situation, as it can be, even if it do not save a life. The growth will be retarded, and great comfort given.

While I am somewhat enthusiastic regarding the use of electricity, both medically and surgically, I am still conservative, and resort to old and well-tried methods when, in my judgment, they are preferable. For instance, if in a case of malignant disease of the rectum or any other part, it would seem to be better to operate with the knife than by electrical means, I should do so unhesitatingly. Where the ordinary snare will readily remove polypi, it is a waste of time and material to employ the cautery-loop. The facts still remain, however, as previously set forth, that in many cases and conditions, even when there are reasons for and against electro-surgery, I incline to the latter, knowing its great value, aside from its convenience. Many operations that are inadmissible under the old methods, for various and obvious reasons, may be safely performed by the skillful electro-surgeon. With better instruments, greater knowledge, and consequently more skill, better results than heretofore await us.

Ulcerations.

We have two general characters of ulcerations with which to deal, with various subdivisions: (*a*) ulcers whose characters depend upon their local condition, and (*b*) ulcers whose characters depend upon their specific origin. Under (*a*) we have the simple healthy or healing ulcer, which needs but little treatment; the exuberant or fungous ulcer; the œdematous or weak ulcer; the sloughing, the phagedenic, the chronic, callous, and indolent, the varicose and eczematous, and the irritable or painful ulcer. Under (*b*) we have the strumous ulcer; the syphilitic, which appears as superficial and deep; the gouty, and the scorbutic. Lupoid, epitheliomatous, rodent, carcinomatous, and sarcomatous ulcers, also, come under this heading.

Exuberant or Fungous Ulcers.—These are due to undue contraction of the tissues, as seen after a burn. The edges are healthy, but the granulations rise above the surface. They bleed readily. There is a purulent discharge. The safest and most radical cure is to reduce the exuberant granulations by applying the galvanic anode with a zinc electrode. Burn off the so-called proud flesh with a current-strength of 10 or more milliampères, and do it thoroughly. Cocaine may be applied if necessary.

Œdematous Ulcers.—These are generally the result of a long use of poultices. Remove the cause, and stimulate the lesion with mild currents applied with the cathode to stimulate to healthy action: 3 to 5 milliampères of current will be sufficient. A sub-variety of ulcer may be termed the inflammatory, or an inflamed ulcer. These may belong to any of the class as mentioned. They are to be treated for the inflammation first of all. A mild and gentle faradic current from the secondary coil, applied with the anode, and by means of a large, soft pad, will be

found very efficacious. Treat daily or even twice daily, for five to ten minutes, or even longer.

The Sloughing Ulcer.—This is generally specific in character, and is a severe form of the inflammatory variety. Treat the inflammation on general principles, and give, later, stimulating treatment, to promote healing, with the galvanic cathode, as already set forth.

The Phagedenic Ulcer.—This, if met with, should be thoroughly cauterized with a strong cathodal current,—50 to 75 milliampères,—or by the galvano-cautery. Being due to a specific micro-organism, the treatment must be thorough and deep. The patient must be under ether.

Chronic, Callous, or Indolent Ulcers.—The most frequent seat of these ulcers is the lower third of the leg, especially found among the poorer classes; the illy nourished. But little can be done unless the general tone of the system can be elevated. The electrical treatment will consist in static sparks to the eczematous skin around the ulcer and the limb generally. Act upon the whole surface of the ulcer with the galvanic cathode, using 5 or more milliampères for a few minutes daily. If this be not convenient, cut a disc of zinc the size of the ulcer, apply it, place a piece of copper on a healthy spot on the skin, connect the two plates with a wire or strip of metal, bandage them firmly, and let nature work the battery for an hour or more. If left on too long, it will be quite painful, especially if the skin under the copper plate be moist. Sometimes I keep the copper plate moist by a flannel cloth wet in vinegar and applied under it. This makes a most excellent method of acting upon a stiffened and painful joint where long-continued treatment is desired.

Varicose and Eczematous Ulcers.—Dependent, as these are, upon a varicose condition of the veins, the treatment will be directed to the cause, and that removed, if possible. (See "Aneurism," etc.) This done, the ulcer and eczema will very readily yield. As before stated, the static spark applied to such conditions is most excellent treatment.

Irritable and Painful Ulcers.—These terms are generally restricted to anal fissures, etc., and have already been considered under "Diseases of the Rectum."

ULCERS WHOSE CHARACTERS DEPEND UPON THEIR SPECIFIC ORIGIN.

Strumous Ulcers.—These are generally due to the breaking down of tuberculous lymphatic glands, the bursting of subcutaneous strumous abscesses, or the ulceration of the so-called strumous nodules, etc. This class of ulcers was considered under the treatment of tuberculous abscess. If the lesion be larger and multiple, as it is apt to be, treat each ulcer separately, and with the inserted carbons, or, in some cases, the zinc electrode. Keep them clean, and use the galvanic applications

every day, or every other day at the least, until the granulations become healthy. In these strumous cases central faradization and galvanization and the tonic treatment should be given. By central treatment is meant applying the current to the back of the neck with the anode, and the cathode on the stomach, or the reverse, as may be desired. Have a large pad on the stomach, one covering the liver and spleen as well; then go over the cervical region with the positive pole, using a galvanic current of 5 to 10 milliampères for ten minutes. If faradism be used, apply in the same way, using a pleasant current. Pass the sponge down the spine also, and run the current directly through the solar plexus. Treat every day for fifteen minutes.

Syphilitic Ulcers.—These will be treated electrically, the same as for phagedenic ulcer, which see. If inflammatory, first subdue that symptom and then proceed. Of course, any local treatment will be unavailing without proper constitutional attention. Gouty and scorbutic ulcers must, like the preceding, receive constitutional treatment, or local applications will avail but little.

Lupus Vulgaris.—This form of ulceration is of a tuberculous character, and is very intractable. It invades the deeper layers of the skin, the whole being finally destroyed if the disease be not arrested. It is very slow in growth, the patient often suffering for years. A case has been under my observation for some years, and under my care at times, which has lasted for over twenty-five years. It covers the face, the right shoulder, axilla, and patches are found on other parts of the body. Very favorable results were reached in this case by electrical applications with the galvanic cathode, except when bleeding took place, when the anode was used instead. The infiltration and disfiguration were so extensive that destruction of the tuberculous tissues with the electrolytic needle was not attempted, although I wished to do so. Professor Shoemaker, who referred the case to me, desired me not to operate with the needles, as he said that, while I might destroy the tubercles and arrest the disease locally, it would manifest itself in the lungs, as it had done for him when he had entirely healed the ulcerations by applications of strong carbolic acid, etc. I may say that Koch's lymph was used faithfully upon this case, with negative results, so far as I have been able to learn. There was less discomfort, no danger, and more real improvement under galvanic applications, combined with the constitutional treatment pursued. A current-strength of 2 to 5 milliampères was used on the lesions, treatment being given every other day for ten or fifteen minutes at a sitting. My carbons were not used on this case. An ordinary electrode covered with absorbent cotton, this again being covered with a piece of Canton flannel, and the whole covering thrown away after each application, was the method employed.

The worst case of lupus vulgaris that it has ever been my misfortune to treat was that of a gentleman from the western part of the

State. The whole face was involved, the nose partly destroyed, and one ear entirely gone. The patient wore a handkerchief as a veil, so great was the disfigurement. The surface bled easily. There was a large patch on the inner aspect of the right thigh. But little could be done here. The galvanic applications gave great relief, however. Taken early, and before the disease has become constitutional, I believe it can and should be cured by electrolysis.

Epitheliomatous Ulcers.—These should be removed as early as possible, and before secondary manifestations take place. If on the tongue, remove the whole mass, including sufficient healthy tissue to insure a cure. Do this by means of the cautery-loop. Pass the wire through the member, it being held firmly by a volsellum forceps, or by a string put through it, and cut through one side at a time with the heated wire. Observe the same precautions as in other cautery operations,—*i.e.*, do not have the wire too hot nor work too fast; this is especially necessary in this operation, the tongue being so vascular. Of course, the patient should be under an anæsthetic. The blood-supply being great, wounds in this locality heal very rapidly.

Epithelioma of the face, or other parts, is to be removed by the needle operation. If on the face, the anodal electrode may be applied to the shoulder or held in the patient's hand. No anæsthetic is necessary. Transfix the growth with two or more needles connected with the cathodal pole; turn on 10 to 15 milliampères and act on the mass for five minutes or more. Remove the needles, insert them again in another place, and repeat the operation. Insert them also at right angles to the first, if you wish to do so much at one sitting; but I seldom make more than two insertions at once. Dress the ulcer with iodoform collodion, and repeat the operation in one week, if necessary. If quite thoroughly done, the mass will turn black and drop off as a scab in that time. This done, act upon any remaining diseased tissue with the needles, and cauterize the seat of the tumor with the negative current, using one of my small carbons for that purpose. Cover again with iodoform collodion, and let it heal without further molestation. Should there be a recurrence, which is not likely, repeat the operation.

Carcinomatous and sarcomatous ulcers are to be treated in the same way as for the epitheliomatous variety, early extirpation by electrolysis or ordinary surgery being the method of treatment. Sufficient explanation has been given as to technique.

Addendum.

Scirrhus of the Breast.—The statement made on page 23 regarding mild currents in cancerous affections may be considerably modified, in the light of an experience with a scirrhus of the breast now and for the past seven months under the care of the writer. The patient when first seen, in December, 1892, presented a scirrhous tumor in the right breast

under and surrounding the nipple, extending fully an inch on all sides. It was of long standing. The patient came complaining of severe and increasing pains, darting in character, with a painful, drawing, or contracting sensation in the parts. Recently there had been a very perceptible increase in the size of the growth; it was very much inflamed, and threatened to break down into an open ulcer.

Immediate extirpation, either by my needle operation or the knife, was urged, but to neither of these would she submit. Mild galvanic anodal applications, followed by the faradic current, were made twice in each week, with sittings of ten to fifteen minutes each. Commencing with the second month, the patient was given the following mixture:—

℞ Fl. ext. rumex crispus,	f℥ij.
Fl. ext. phytolacca dec.,	f℈ij.
Alcohol,	f℥iij.
Water, to make	Oj.

M. Dose: One tablespoonful three times a day.

The breast was kept dressed with the following ointment:—

℞ Fl. ext. rumex crispus,	f℈iv.
Fl. ext. phytolacca dec.,	f℈j.
Evaporate and make into an ointment with	
Yellow wax,	℈iij.
Benzoinated lard,	℈iv.

M. Apply freely.

Improvement was perceptible from the first. Later on I used a concentrated fluid extract of fresh poke-berries directly to the tumor (under and around it) by means of the galvanic cathode.

The results of treatment so far are that all painful sensations, as well as the "drawing," have subsided, the inflammatory character has disappeared, and the tumor has lessened fully one-half in size. Considering the serious nature of such growths, much has been accomplished, and I feel hopeful of a complete cure.

The internal medication and the ointment were suggested by Dr. Carpenter in the *Lehigh Valley Medical Magazine*, in which he reported a case of carcinoma as practically cured by such means. As there was improvement under the electrical applications before commencing the medicine, and more rapid progress after the cataphoric applications, I am satisfied that the latter played an important part in the treatment. The whole method of treatment is well worthy of further trial.

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INCONTINENCE OF URINE; ORCHITIS; HYDROCELE; SPERMATORRHŒA; GONORRHŒA.

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Before discussing the treatment of the various diseases in this section, it might be well, both for the sake of brevity and clearness, to state certain rules which apply equally to all electric treatments :—

1. Before giving electricity to patients it is always well to inquire if they have ever had it before, how it was administered, and what the results were. There are very few people who have not, at some period of their lives, "taken the battery," the battery in question having been, in all probability, a small faradic machine of little or no strength, and the current having been taken by means of the two handles which come with the instrument. It is hardly necessary to state that little or no benefit was derived from this treatment, and, as a consequence, there remains in the patient's mind a very natural prejudice against this agent. In cases of this kind, the physician should take pains to explain the difference between the old-fashioned hap-hazard methods and modern scientific electro-therapeutics. He should show them how natural it was that failure should have followed the former method, and at the same time point out some of the brilliant results which have followed the application of this agent according to modern methods.

2. It is a good general rule to lay down that electricity should be given in the reclining position, and this is especially applicable to treatments applied to the pelvic organs. One of the most convenient appliances for this purpose is an ordinary gynæcological chair, as it can be tipped back at any angle which is most convenient for the case under treatment. It should be remembered that certain persons are very liable to faint-turns, and one might come on while such a person was taking an electric treatment, as has occasionally happened to the writer. The advisability of this rule is so apparent that further stress will not be laid upon it.

3. Care should be taken that the wet electrodes do not come in contact with the patient's underwear and make them damp. This can best be avoided by covering the electrode with a towel. In careless use of the larger electrodes the underclothing next the skin may become soaked over quite a large surface, and a patient allowed to leave the office on a cold winter's day in such a condition might suffer serious consequences therefrom.

4. Always begin and end an electric treatment with the current at zero, thus lessening the danger of sudden shocks to your patient, and also that of short-circuiting the battery. Simple as this rule is, it will save much annoyance if always followed; so that the physician finally comes to do it mechanically, no matter what happens to draw off his attention. This is specially true of the modern instrument with its somewhat complicated switch-board, where a single mistake in turning a switch may give the patient a severe shock.

5. The first treatment should always be tentative in its nature; a short sitting and a weak current. There is a great difference in the susceptibility of different people to electricity, some being very much more so than others. All patients should be treated in the beginning as if they belonged to this susceptible class. Later on it is very easy to increase the dose; whereas, if it is given too strong at first and a bad headache be brought on, or an attack of faintness, the patient will very likely become disgusted and give the whole thing up.

6. If a patient complain of feeling faint or sick during treatment, turn the current off immediately and give it up for that day. This is generally an indication that too strong currents are being used, and the dose should therefore be reduced in subsequent treatments. Moreover, special caution should be used in the case thereafter, and the treatment should always be short; about five minutes.

The writer is confident that he who would make a successful electrician will find it well worth his while to take careful note of these suggestions and carry them out in his practice. Success in any art must depend upon attention to details, and nowhere is this more true than in the field of electro-therapeutics. There are many things to distract the operator's attention when about to give electric treatments, and at the same time nothing makes such a bad impression as bungling at this time. It is on this account that it is desirable to have a regular system, which soon comes to be a matter of habit, so that it is done almost mechanically. First, get your patient all ready, in the position which is desired, and the clothing so arranged at the points where the electrodes go that these may be applied without difficulty. Now see that your electrodes are thoroughly soaked in water, the hotter the better. Do not hurry over this part, for the current never flows well through half-soaked electrodes. The electrodes are then adjusted, after which the current, which should have been at zero, is gradually turned on. When the treatment is finished, the current should be brought to zero again before the electrodes are removed. On removing the electrodes it is natural to squeeze them together in order to express the water, and, if two or three cells still remain in circuit, the battery is thereby short-circuited and perhaps serious injury done to a delicate milliampèremeter. Another detail well worth following is, when the current is turned off, to turn back to its place every switch which has been used during the treatment. It takes

but a moment to do this, and the battery is then all ready for use again.

A principle of paramount importance in electro-therapeutics is the dual action of this agent. We have the local specific action on a certain organ, and, in addition, the tonic and stimulant action on the system at large. The smaller the electrodes and the nearer they are together, the less diffusion of the current there will be, and the smaller the effect on the system at large; while with larger electrodes and greater distances between them this general systemic action is proportionately increased. In such treatments as general faradization and central galvanization it is this systemic action alone which is sought for. On the other hand, in certain strictly-localized treatments—as in that for orchitis, to be described farther on—the systemic effect is *nil.* It frequently happens, however, that local diseases are favored or accompanied by general debility of one kind or another, and, as electricity is one of the best agents for combating this condition, the two forms of treatment are often combined, as we shall see in the first disease we consider.

Incontinence of Urine.

Incontinence of urine may be termed a true nervous affection, for, although it often depends upon organic lesion, this lesion is to be found not in the bladder itself, but in the vagina, rectum, or some other neighboring organ. In such cases the lesion produces the incontinence by reflex action. As this is the real character of very many cases of incontinence, it follows as a logical deduction that, when a case presents itself, the first thing to be done before any treatment is thought of is to make a careful investigation, in order to find out the cause of the trouble. If this is found to be a caruncle at the mouth of the urethra or some rectal irritation, it should be treated first, and it is very probable that with its cure the incontinence will also disappear. This matter of causation and reflex action is one of great importance in functional nervous disease, and if more attention were paid to it there would not be so many failures to record in the treatment of such cases by means of electricity.

One of the most important principles in electro-therapeutics is that proper cases should be chosen for treatment, and, if this rule be ignored and this agent be used in a generel and hap-hazard manner, it must not be wondered at if many failures result. There are cases where incontinence of urine may be traced directly to some lesion in a neighboring organ, and yet when this lesion is cured by appropriate treatment the incontinence still persists. This is not necessarily a proof that a mistake has been made, but is simply an example of the principle that a functional trouble which was originally secondary to some other preexisting affection may in time become itself independent and continue to exist after the trouble which was at first the exciting cause has been removed. Such a case would be an extremely favorable one for electric

treatment, although in its first stage, before the cause was removed, it would probably have proved entirely rebellious to the most carefully-applied currents, and simply gone to swell the list of failures attributed, often unjustly, to this agent.

The character and etiology of a case may have an important bearing in determining the method to be employed in applying the electricity. Take, for example, a case of incontinence in an old man with an enlarged prostate gland. An examination reveals the fact that the dribbling of urine is owing to an overfilled bladder, which, in its turn, depends upon the prostatic hypertrophy. This is an eminently proper case for electric treatment, although the regular method to be described later on for incontinence would probably fail to give satisfactory results. The evident indication would be to attack the enlarged prostate according to the original and excellent method of Dr. Newman, of New York, which will be found fully described under affections of that organ. When a case of incontinence presents itself for treatment, give it first and foremost a most careful examination, in order to find out, if possible, what is the existing cause. If it can be readily traced to some organic lesion existing in the adjacent parts, then this should be first relieved by appropriate treatment. If the incontinence is stopped by this indirect method, then there is no use for the employment of electricity or any other treatment; but if it still persist, then the direct treatment to be described farther on may be employed.

There may be cases of incontinence which can be traced directly to some exciting cause, but which cause cannot be removed. Such a case would be the incontinence which frequently occurs during the early months of pregnancy, where the trouble is undoubtedly of reflex nervous origin. In such a case a few mild electric treatments very cautiously given, so as to avoid all danger of bringing on an abortion, would very likely stimulate the nervous mechanism of the bladder to resist this interference with its functions, and bring about a cure. Incontinence of this kind would naturally have very little pathological importance, and the main object of the treatment would be to relieve the patient from needless annoyance.

We come now to a class of cases more obscure than the preceding, where the causes, whatever they are, do not appear at once, and, indeed, may not be discovered at all. This does not by any means imply that the causes do not exist, but simply that they are hidden from us, in the present somewhat hazy state of our knowledge of nervous phenomena. There is this to console us, however, that if we cannot find out the etiology of these cases, we have at least discovered in electricity an agent which is wonderfully potent for their relief, for these cases of incontinence have offered some of the most brilliant examples of cures performed by it.

There is one principle, however, well known to the student of nervous phenomena, which explains to a certain extent some of these cases, and at the same time gives us a valuable hint as to treatment. It is this: that

nervous depression in general, with its concomitant symptoms of increased irritability and undue susceptibility to reflex action, is a condition very favorable, if indeed it may not be reckoned a cause, of urinary incontinence. Take, for example, the case of a child of either sex, between the ages of seven and ten years. A careful examination does not reveal any organic lesion to account for the incontinence; the rectum and urethra seem perfectly normal. Further questioning reveals the fact that the child is excessively nervous. He has perhaps shown unusual aptitude in his studies, and the parents, proud of his attainments, have allowed him to go too far in this direction, and to spend in poring over his books the time which should be given to play and exercise in the open air. It is in these cases that the tonic action of the spinal treatment, to be referred to later on, is of special benefit; and, in a case such as has just been described, a cure can be almost assured, if proper hygienic measures are taken along with the treatment.

Much space might be taken up with the discussion of the different forms of incontinence, as it occurs in children, in adults, and in the aged; but such a course would hardly be appropriate in a work devoted exclusively to treatment, and, moreover, the method to be recommended is of a comprehensive nature, which includes the whole mechanism of urination, and is therefore calculated to reach the trouble, whichever part of the apparatus is affected.

Before passing on to the discussion of treatment a word may be said in explanation of the plan to be followed. The universal complaint against works of this class is, that the directions for treatment are too general and too vague. Almost all forms of treatment have been tried by enthusiastic electro-therapeutists in a great variety of diseases, and in many works this fact is about the only direction to be found in the treatment of any given disease. It will be the aim of the writer of this section not to enumerate a list of treatments which have been tried by various experimenters, but to describe, in as clear a manner as possible, that method which the accumulated experience of himself and others shows to be the best and most likely to cure. Should this treatment fail in any given case, then the physician would naturally go on and try other and perhaps newer methods, according as his own judgment and experience dictate.

Treatment.—When one refers to his text-books for directions in the matter of treatment, he generally finds galvanism and faradism both recommended, with the preference perhaps given to faradism, but with few specific directions as to which one he should use and just how to employ it. The agent to use in the local treatment of the bladder is faradism. Not only is it recommended by Erb, who may be called the father of the modern science of electro-therapeutics, but experience verifies his statements and continues to give it the preference.

When disease involves any internal organ we have the choice of two

methods of treatment open to us: the percutaneous or external method and the internal method. In the treatment of the bladder for incontinence we have this choice, and we may adopt the plan of driving the electricity through the unbroken skin from both poles, or, the more direct and certain method, through the urethra. Do not waste your time on the former or percutaneous method. It is very apt to end in failure, and is not worth the trouble of trying it. Although an occasional mild case might be cured, it would fail in many others, and only serve to bring the art of electro-therapeutics into disrepute. There is, however, one exception to this rule: where slight incontinence is present as a result of advanced spinal trouble, which latter you are carefully treating with electricity, it may not be worth while to complicate the treatment—which is already long enough and complex enough—with urethral electrization. As the treatment should be mainly directed to the spine, the bladder symptoms may be reached by placing the negative pole, attached to a flat sponge-electrode, about twelve square inches in surface, close above the symphysis pubis, and pressing it firmly down, while the positive pole rests on the spine, either in the lumbar or cervical region. In this case galvanism would naturally be used. These same directions would apply to mild degrees of retention occurring likewise as a symptom of spinal trouble.

With regard to urinary troubles which occur in the course of chronic affections of the spine, a mode of treatment has been advocated by Professor Benedikt, of Vienna, which the writer has also used with success in a number of cases, and can therefore recommend. It is the treatment by means of static electricity. Direct static sparks are drawn from the hypogastric region, just over the bladder, and also from the spine along its whole extent, from the back of the neck to the sacral region. The electrodes used are, first, the small brass ball (one inch in diameter). If this is well borne, and the case seems to require more heroic treatment, then it is replaced by the large ball having a diameter of two and one-half inches. When this treatment is given as an auxiliary to spinal galvanism, it is applied last, and the sparks are given for two minutes altogether,—one minute to the bladder and one to the spine. This is sometimes extended to four minutes,—two for each of the above-named regions.

We know that incontinence is not necessarily a strictly local trouble, but may frequently have its origin in the spine; and in certain cases the brain itself seems to be, to a certain extent, involved. A proof of this is found in the fact that the affection sometimes occurs as an epidemic, in schools or asylums for children. It is on this account that the treatment should not be limited to a simple local application to the bladder, but that the spine should also be included in the field of action of the current. We may here repeat the injunction already given: do not waste time with the percutaneous method. Attack the trouble directly, by placing

the negative pole in the urethra itself, if it only enter half an inch. In children, where the canal is small, the ordinary urethral electrode may be replaced by one made of copper wire. In very obstinate cases, where ordinary methods fail, it may be pushed down as far as the neck of the bladder. The positive pole is attached to a medium-sized sponge-electrode, twelve inches square, and applied just above the symphysis. The faradic current is allowed to pass for from three to five minutes. It should be strong enough to cause slight pain. The electrodes are applied in the same way in both sexes, except that in the case of the female it is only necessary to introduce the electrode into the urethral opening, since the canal is only one and a half inches in length in the adult and proportionately shorter in the child. It is not necessary that the electrode itself reach the neck of the bladder, although this is sometimes of advantage. The instrument coming into contact with the moist and delicate membrane of the urethra, itself a most excellent conductor, the current is conducted more directly and its action is far greater than that of a stronger current when forced through the skin of the perineum or some other neighboring region.

In the case of little girls it has been recommended to place a sponge, which should serve as an electrode, between the labia, in order to avoid introducing an instrument into the urethra, where it might set up inflammation. In the writer's opinion this departure from the regular method is not to be followed. The danger of inflammation is more imaginary than real if the indication for the current, only strong enough to cause slight pain, be not overstepped. The infantile urethra being very sensitive, this indication will keep the current within a very moderate limit, where inflammation will not occur.

This comprises the direct method and will cure many cases of incontinence. There are others, however, that are not so simple, and in these the direct treatment alone will not suffice, but must be united with spinal galvanism. In view of the great uncertainty which exists as to the exact causation of this affection, it is a good rule to treat all cases of incontinence with the direct treatment as just described, and then to apply spinal galvanization for three minutes more, positive pole at the back of the neck and negative just above the symphysis pubis. A current of about 15 milliampères stabile. In adults as high as 25 milliampères may be given. With this addition the treatment is still within the ten-minute limit, which does not constitute a very long treatment, and the results will certainly be very much more satisfactory. The treatments should be given every other day.

To recapitulate. The treatment which may be called the best—that is to say, calculated to cure the greatest number of cases of incontinence—is as follows: Local faradism for three minutes, spinal galvanism three minutes. At the third treatment each may be lengthened to four minutes, and at the fifth to five minutes. Very many of these cases will be

cured before the fifth treatment. If not, the treatments should be continued until ten, fifteen, or even twenty have been given. At this point the physician might be pardoned for feeling discouraged and inclined to conclude that the method was a failure. In these obscure and obstinate cases, however, that seem to resist all possible means, I believe there is still a form of electricity which will often enable us to conquer, and that form is the static. The patient is placed upon the insulated platform and static sparks are drawn from the region of the bladder and spine, as already described, for four minutes. The patient then takes the simple static charge for six minutes more, the negative pole forming the ground. This makes the whole treatment ten minutes in length, which should be the limit of all treatments, either galvanic, faradic, or static, except in very exceptional cases. It is extremely doubtful if anything is ever gained by transcending this limit, and, as a rule, it should not be reached. The writer is well aware that many physicians are not provided with a static machine, and therefore would be unable to use this form of electricity in the treatment of any case; at the same time, as a knowledge of the value of this form becomes more widely diffused, the machines in question are becoming more and more common. Moreover, it may be said that in the present state of the science of electro-therapeutics, and the recognized value of this last-named form, it would be equally impossible for a physician to practice scientific electricity without it, or for a work of this character to be published without mention being made of it.

Before leaving this subject, it should be said that the writer does not by any means underrate the value of galvanism as a stimulus to muscular tissue, and, indeed, in certain cases it is superior to faradism. In the disease in question, however, he is convinced that the treatment recommended will be found to be the best; combining, as it does, the powerful direct stimulus of faradism to the muscular tissue involved and the profound alterative action of the galvanic current upon the nerves and nerve-centres.

Orchitis.

This disease being entirely different from the one just considered, the treatment also differs materially. The only form of this disease in which much can be hoped from the electric treatment is the ordinary acute form. It would hardly be worth while to attempt it in those forms due to tuberculosis or syphilis. As far as concerns the electric treatment, it is of no importance whether the inflammation attacks the gland proper or the epididymis, as the method of application is the same in both cases. The treatment is extremely simple and easily carried out. It may be called direct galvanization, and is performed as follows: The inflamed mass, whether one or both glands are involved, is slightly raised and supported on a pillow. Two medium-sized flat sponge-electrodes are placed one on either side of the mass, so that the current passes, in a transverse direction, directly through the inflamed organ. The relative

position of the poles is indifferent. Great care should be taken in applying the electrodes; the contact should be as close and perfect as possible, but, at the same time, they must not press hard at any one point, on account of the sensitiveness of the inflamed testicle. Be sure that the current is at zero when the electrodes are applied, and then raise it very gradually, cell by cell, up to 10 milliampères. Let it rest there for a couple of minutes, and then just as gradually bring it down again. When the current is reduced to 2 milliampères, reverse the poles and increase again up to 10 milliampères. Four such alternations should be made, when the current is again to be brought down to zero and the electrodes removed. The whole treatment, from the time the current is first turned on to the end, should occupy ten minutes.

If there is a caution to be given in this treatment, it is to avoid sudden changes in the current-strength, and do not by any means reverse the poles while the full current is flowing. This is especially true in the first days of the disease, when the inflammation is intense. Neglect of proper precautions at this stage may aggravate the inflammation instead of subduing it, and cause suppuration to occur. The treatment may be given every day.

Lewandowsky recommends galvanization of the spermatic cord in addition to the treatment above described, but the writer does not consider this an important adjunct to the direct treatment. The affection being a simple localized inflammation, the more direct the treatment, the better.

The electric treatment naturally renders impossible the method by strapping, so frequently recommended in this disease, but it does not interfere or contra-indicate the use of other means, either local or internal. In any case proper support to the inflamed and enlarged organ should never be omitted, otherwise little can be hoped from any method of treatment. If a simple acute case of orchitis should become chronic through neglect or improper care, it is none the less a proper one for electric treatment. Cases of two or three weeks' standing, where the pain and acute symptoms have to a great extent gone down, may be treated with currents of 15 milliampères, still following the method prescribed in the acute form. The question is now mainly one of stimulating the absorbents to carry off the inflammatory exudation which renders the mass so large and heavy. If this dose be well borne, and absorption seem to go on rather slowly, the current may occasionally be run up to 20 milliampères and then down again to 10. Instead of four alternations of the current, eight may be made, and the various changes may occur more rapidly than in the acute form; for these very changes which were then so dangerous, now that the liability to suppuration has to a great extent passed away, are active agents in promoting the absorption.

The new method of treatment known as cataphoresis, or electro-medication, which was first brought out by Dr. Frederick Peterson, of

New York, as far back as 1889, has also been made use of for the treatment of orchitis. This method of treatment depends upon the principle that the galvanic current, in its passage through the tissues, may be made to act as a carrier of medicinal substances; but it is fully described by Dr. Peterson himself in another part of this work, and therefore it will not be spoken of further here. Dr. Hunter McGuire, of England, claims to have had great success in treating a case of chronic orchitis, by means of tincture of iodine introduced into the inflamed gland according to this method of cataphoresis. If Dr. McGuire's claims can be substantiated, then this method must be looked upon as the best in the treatment of this affection; but the cases are still too few to enable us to judge of its relative advantages and disadvantages, and we must therefore wait for the future to decide.

Hydrocele.

The treatment of this disease offers one of the most favorable conditions for the employment of electricity, and it is more than probable that, when a knowledge of this matter becomes more diffused, all other and more uncertain methods will be given up for this one. Like numerous other matters, this subject is generally treated, in the ordinary works on electricity, in the most vague and unsatisfactory manner possible. That is to say, all possible methods are mentioned as having been tried; certain wild claims for remarkable results are quoted, and the matter is left there; so that the seeker after information is left in doubt as to what method he should really pursue. Galvanism and faradism have both been tried in this affection, and in all kinds of ways; percutaneous, or through the skin, as well as by puncture. As to the percutaneous method,—that is, an electric current passed through the unbroken skin by means of suitable electrodes,—it is so far inferior to the others that little need be said of it. As to faradism applied in this way, the author very much doubts if it would produce any result whatever. A powerful galvanic current, applied percutaneously for a long time to a hydrocele, might finally cause its absorption, just as the effused fluid in a rheumatic joint is absorbed. This treatment would be so slow and unsatisfactory, however, as to be hardly worth the trial; except in the case of some very timorous mortal, who positively refused to submit to puncture, and who was willing to bear the annoyance and expense of prolonged treatment.

The only method which is at all satisfactory or worth considering is some form of galvano-puncture. Probably the best method known to-day is that of negative galvano-puncture, and it is performed in the following manner: A large flat electrode is placed upon the inner surface of the thigh, corresponding to the affected testicle. The larger this electrode, the better, so as to give a free path for the current to enter the body. The negative pole is attached to a needle-electrode and introduced into the centre of the tumor, care being taken not to wound the testicle, just as in the ordinary puncture with the trocar and cannula. This should

never be done, however, with the patient in a standing or even sitting position, as often occurs in simple puncture. As a general rule, patients should always be in a reclining posture when powerful galvanic currents are given, and this operation is no exception to the rule. The needle to be used should be insulated to within half an inch of its point, but does not require to be of platinum, since the negative pole does not corrode. It is important that the needle should be insulated, otherwise a certain amount of the electricity is carried off at the point where the needle traverses the integument, and the electrolytic action is proportionally weakened. The negative pole being really the active one in this process, negative puncture as above described is quite as efficacious and much simpler than bipolar puncture, where two needles are inserted into the sac instead of one. The current, which should have been at zero, is now gradually turned on until a strength of 40 milliampères is reached. It is important that this last direction should be followed, for if neglected serious results might ensue, either in the way of causing inflammation or by giving a severe shock to the patient. Some people are specially sensitive to electricity, and if a powerful current should be suddenly sent through such an individual the results might be serious. Let the increase be very gradual, therefore; and if at any time the patient complain of a very severe burning, stop a minute until it ceases, and then continue the gradual increase of the current until 40 milliampères are reached. It should be held here for five minutes and then just as gradually decreased to zero. An ordinary man should be able to stand this operation without an anæsthetic, but, in cases where the patients are very nervous and sensitive, ether may be given. If the electrode on the thigh is not large enough or the contact not firm and close, then there is great danger of blistering the skin. Weaker currents than this may be used, but they are not as apt to give satisfaction, and the cure will not occur so quickly.

One treatment of this kind is sometimes sufficient to cause the complete absorption of the effused fluid and the cure of the affection. Three or four may be required, however, and in this case they should be given at intervals of one week. As a rule, two will be sufficient. After the operation the patient should remain in bed for two or three days, in order to guard against the danger of inflammation. After the puncture the scrotum may be strapped by applying small strips of adhesive plaster in such a way as to completely surround the tumor, and, by exerting gentle pressure, hasten the absorption. As the tumor diminishes in size this dressing should be renewed, so that the pressure may be kept up. In addition to the strapping, the mass should be so bandaged that it is always supported and never allowed to drag.

Last year Dr. Gautier, of Paris, editor of the *Revue International d'Electrothérapie*, brought out the following method of treating hydrocele, which he claims to cure in one sitting. It is based on the principle

of electrolysis, and depends upon the decomposition of iodide of potassium by means of the galvanic current. It will be best explained by citing a case in Dr. Gautier's own words :—

The patient was a man, 29 years old, who had noticed that his right testicle increased in size ever since the age of sixteen. A year before he came into the doctor's hands the growth had become so annoying that he had submitted to an operation. The tumor was punctured and a solution of iodine injected into the sac. This operation was followed by intense inflammation of the scrotum ; the sac rapidly filled again and the tumor continued to increase in size, until the operation performed by Dr. Gautier took place. The sac was punctured without an anæsthetic and 620 grammes of liquid were drawn off ; 70 grammes of a solution of iodide of potassium (1 to 20) were now injected through the cannula without causing any pain. A large needle, with the greater portion of its length insulated, was now introduced through the cannula and connected with the positive pole, the negative pole being attached to a large clay-electrode and applied to the thigh. The sitting lasted twelve minutes and was very well borne, in spite of an intensity of 18 milliampères. In the midst of the treatment the patient experienced a shock, and the needle of the galvanometer showed that the current had been broken. This breaking of the current, which should be avoided, was due to the fact that the quantity of liquid injected was insufficient. In repeating the operation I should not hesitate to inject 200 grammes of a 1-to-30 solution ; and I should prolong the sitting to twenty-five minutes, with a moderate intensity. No reaction occurred ; the patient was able to get up on the sixth day, and three months after the operation there was no return of the trouble.

As to this treatment of Dr. Gautier's, the matter is still *sub judice*, and it is yet to be demonstrated that it is a better and safer treatment than simple galvano-puncture, already described. It seems natural to suppose that this injection of iodide of potassium and subsequent liberation of iodine within the sac would give a certain risk of inflammation, just as the injection of tincture of iodine does. The method is still too new and untried, however, to say with precision just how great this risk is.

To conclude, the treatment of negative galvano-puncture, already described, is a most simple, satisfactory, and, when properly performed, harmless form of treatment, and is therefore recommended as the best that we know of to-day, simply because it has stood the test of experience. If the future shall show that Dr. Gautier's method is more certain than the former, and equally harmless, then it must be given first place ; but for the present we must await the result of further and more extended trials.

Spermatorrhœa.

Spermatorrhœa, or the loss, more or less continual, of semen, without orgasm or ejaculation, is here treated as a disease entirely distinct from nocturnal pollutions, which arise from other causes and require different treatment. Before attempting treatment it is very important that a careful diagnosis be made, as this disease is often confounded with gleet, resulting from stricture of the urethra. The treatment of these two diseases being entirely different, a mistake in diagnosis would inevitably result in a failure to cure, for which electricity would have to bear the

blame. As the discharges in these two diseases are extremely similar in appearance to the eye, it follows that the only certain way to make the differential diagnosis is by means of the microscope.

Spermatorrhœa generally owes its origin to gonorrhœal inflammation of the urethra, but it is itself a functional disease, and depends upon atony and relaxation of the ejaculatory ducts and seminal vesicles. Like all diseases of this character, there may be a close relation between it and the general condition of the system, and therefore, if this latter is depressed, a certain part of the treatment should be directed to building it up, precisely as in the case of incontinence of the urine. It should be said, however, that in a certain number of cases the system at large seems to be entirely unaffected by the seminal loss, or, in other words, the disease is strictly local in its character. Such cases, of course, require only the direct treatment.

As to the direct treatment, we have again the same choice as in the treatment of incontinence of the urine,—between percutaneous electrization and internal treatment through the urethra. As in the first case, our choice falls unhesitatingly upon the latter method. Do not waste time with the treatment through the skin, for it is not worth while; but strike directly at the root of the matter, by applying the current to the mouths of the ejaculatory ducts in the urethra. The current to be used in the treatment of these cases is the galvanic. The negative pole is to be applied to the prostatic portion of the urethra by means of the ordinary sound-electrode with a metallic bulb. The positive is attached to a flat sponge-electrode twelve square inches in surface, and applied to the lower lumbar region, in the median line; in other words, to the small of the back. A current of 3 milliampères should be allowed to pass for five minutes. The urethral electrode should then be removed and spinal galvanization employed for five minutes longer, positive pole at back of the neck, negative at small of the back. Flat sponge-electrodes of medium size (twelve square inches). Current starting at zero and gradually raised to 25 milliampères, if the patient be over 18 years of age. If he be a boy under eighteen, 20 milliampères should be the limit. At the end of the treatment the current should be decreased as gradually as it was increased at the beginning. The five minutes should be counted from the beginning to the end of the treatment, not simply for the time that the current is at the maximum. In giving spinal treatment always watch the upper electrode, for the upper dorsal region is so bony and uneven that burns of the skin readily occur.

Transverse faradization of the testicles has been recommended in this connection, but it is an uncertain and rather irrational treatment at best, and not worth the extra time required to try it, in the writer's opinion. All urethral treatments have a limitation, in that the canal will not bear strong currents, and it is on this account that we are limited to such a small dose of galvanism. If strong currents are used there is

immediately hypersecretion, irritation, and possibly inflammation of the membrane lining the canal; so that the injury caused may be worse than the trouble for which the treatment was applied. It is for this reason that the current-strength is not increased when the dose of 3 milliampères fails to effect a cure. If after ten galvanic treatments the case fails to improve, it should be replaced by faradism. The electrodes being applied in the same manner as before, a faradic current of just sufficient strength to cause a slight burning sensation is allowed to pass for three minutes, after which the spinal galvanization is given for five minutes as before. These treatments are best given every day to secure a speedy cure. If this be not convenient, however, every other day will do very well. Whether it is that the higher voltage and rapid interruption of the faradic current enable it to do its work quicker than the galvanic is not certain. Whatever the cause may be, the writer's experience has led him to the belief that in the use of ordinary currents the relation of the galvanic and faradic treatments, in point of time, should be as five to three. This rule is only applicable when ordinary currents are used, for in the use of very strong galvanic currents, over 100 milliampères, the time of their application is necessarily short.

The sensitive condition of the urethral mucous membrane is another factor which renders a short application of the faradic current desirable. Moreover, the indication as to the strength should be carefully followed: not stronger than is sufficient to produce a slight sensation of pain or burning. Certain authors have advised against this intra-urethral method, on account of the danger of setting up a urethritis. Although the writer denies that this danger is great enough to counterbalance the advantages of the treatment, he is glad to mention it, as an occasion for emphasizing the importance of caution in this regard. Internal electric treatment, like internal urethrotomy, might have very serious consequences if recklessly or carelessly performed; but such results should not be laid to the score of the operation itself, but rather to him who performed it. Moreover, a certain amount of knowledge and experience is required for the successful performance of the former as well as the latter.

It is pre-eminently true, of electro-therapeutics in general, that it has had to bear the blame of much unsuccessful treatment, which was really owing to ignorance and carelessness on the part of those calling themselves skilled electricians. If the physician trying this method will follow these three precautions already laid down, the writer is confident that he will have no cases of urethritis on his conscience. They are: 1. Make the first treatment merely tentative, letting the current pass for—say—one minute only. 2. Do not prolong the passage of the faradic current through the urethra for more than three minutes. 3. Do not be tempted to exceed the limit for the faradic current: only strong enough to cause very slight pain. It would be far better to come within this limit than to go beyond it. In this form of treatment the operator must

not let himself be guided by his experience in the use of faradism as applied through the skin. It must be remembered that, in the treatment in question, the active electrode in the urethra is in close proximity to the seat of the trouble; and, as very little resistance is offered by the lining membrane of the canal, a current too feeble to have any action through the skin might be quite efficient in the urethra.

In conclusion, let me refer to a fact that has a wide significance, but which has a special application to the disease under consideration. The best of treatments will fail to relieve if the circumstances under which they act are unfavorable. This is specially apt to be the case in spermatorrhœa, on account of the frequent prominence of the mental element. A man who is suffering, perhaps, with only a slight case of this affection will get the idea firmly fixed in his mind that his manhood is gone, that he is doomed to impotence, that he can never marry, and a whole train of dismal forebodings which not only render his life wretched, but produce a most unfavorable effect on the general health, which, in its turn, acts to aggravate the local trouble and retard its cure. In a case of this kind the treatment, in order to be effective, must be moral or psychological, as well as electrical. The first thing to do is to remove, as far as possible, this morbid mental condition by a plain statement of the facts of the case, and the excellent prospect of a complete cure which a rational mode of treatment holds out to him. This will often produce a complete revulsion in his mental condition, and from a despondent, hypochondriacal invalid he will become a hopeful and rational man again. The improved mental condition will react upon his physical state, his appetite will improve, his nerves strengthen, and the electricity will act to remove the local trouble.

In other cases great mental and nervous depression is produced by intellectual overstrain or too close confinement to the store or office. In such cases an excellent way to begin the treatment is to send the patient away for a vacation of two weeks or, if possible, for a month. When he returns his general condition will be greatly improved, and the electric treatment, if commenced at this time, will in all probability act rapidly and favorably upon the spermatorrhœa.

There is still another class of cases, very different from any of the preceding, where the disease is absolutely and entirely local. Not only is the general health perfect and the mind normal and free from morbid fancies, but the patient is apparently in the enjoyment of full sexual power, both erection and ejaculation being normally and satisfactorily performed. In a case of this kind it is hardly necessary to apply the spinal treatment. The trouble being confined to the ejaculatory ducts and seminal vesicles, the direct treatment through the urethra is all that is necessary.

It should be said, however, that these idiopathic cases are often extremely obstinate, and require a much longer time to cure than the other forms.

Gonorrhœa.

The treatment of gonorrhœa by electricity is a subject which the conscientious writer can hardly approach without misgivings. Of all the extensions which the field of electro-therapeutics has had in these later years, this attempt to treat acute infectious inflammation is, perhaps, the wildest and most daring leap that has been taken. Let it be remembered that the fathers and founders of our science never dreamed of applying electricity in such forms of disease, and that not a word on the subject is to be found in their writings. This matter has only been thought of for a short time; so short, indeed, that we hardly know just where we stand. Certain investigators refuse as yet to announce the result of their researches on this subject, as they have not yet completed them; and, altogether, it behooves us to be specially cautious with regard to the statements made in a work of this character.

We may divide this subject into two parts for our consideration: (1) gonorrhœa proper, or acute infectious urethritis; (2) chronic urethritis, or gleet.

As to the first-named disease, claims have been put forth by certain investigators which are little less than extravagant, when viewed in the light of known facts. For example, a certain writer claims that in the incipient stage, while the discharge is still mucous, and before it becomes thick, a few cells for a short time will completely abort the disease. As to this claim, the writer would simply say that it is absolutely without confirmation, and that a wider experience will probably show it to be not well founded. Another writer claims that by using the positive pole in the uterus and passing a current of 120 milliampères for ten minutes the discharge soon lost its purulent character and became thin and watery. It was necessary to place the positive pole in the uterine canal, since the sensitive urethral mucous membrane could not stand anything like this dose of galvanism.

Let us stop and consider for a moment the microbic aspect of this subject. We know, beyond question to-day, that acute gonorrhœal inflammation is due to the presence of a specific microbe, the gonococcus, and that therefore the curative action of any agent, in this disease, must depend upon its power to destroy this noxious agent. Careful experiments have been made, in order to determine the destructive action of the galvanic current on this germ. Apostoli and Laguerrière, in a very carefully conducted series of researches to determine the power of this destructive action, were able to demonstrate the following principles: 1. The microbicidal action of the galvanic current is limited entirely to the positive pole, and is probably due to the nascent oxygen which the electrolytic action of the current sets free at this point. 2. The current must have, at least, a strength of 50 milliampères to have any microbicidal action whatever. Its action at this point is extremely feeble, and

to be surely fatal the strength should be between 200 and 300 milliampères. If the current is less than 50 milliampères it not only does not destroy, but it has a revivifying action upon the microbes, owing to the presence of oxygen in very small quantities.

In view of these facts, it seems extremely doubtful that, with the positive pole in the uterus or vagina, a galvanic current could have any influence upon the germs in the urethra. Still less is it to be hoped that a small current of a few cells, even if put directly into the canal, is going to destroy the gonococci and abort the disease. Were gonorrhœa a simple inflammation like orchitis, then we might hope for some result from the alterative action which even weak currents possess. Dr. Gautier, of Paris, who has done so much for the science of electro-therapeutics, recommends the use of the positive pole in the urethra, with a current of 25 milliampères, but even this seems hardly strong enough to have a decidedly destructive action upon the gonococci.

In view of all these facts, it must be acknowledged that the treatment of acute gonorrhœa by electricity is to-day far from satisfactory, and that a treatment that shall destroy the cause of the disease, and at the same time not be too destructive of the delicate urethra itself, has not yet been found. The science of electricity is advancing with giant strides, however, and what is unknown to-day may be revealed to-morrow. In the writer's opinion, the great difficulty will always be to find a method of applying a current strong enough to have germicidal action without injuring the delicate lining membrane of the urethra. It should be said that after this membrane has suffered from inflammation it may become thickened and indurated, and so be able to bear stronger currents than when its condition is normal. It is on this account that in gonorrhœa, and still more so in gleet, stronger currents may be given than would be tolerated in the diseases already treated of.

If we pass now to the second division of our subject, we find a much more satisfactory field. It has been shown that chronic gonorrhœa, or gleet, is not dependent upon the existence in the urethra of any specific germ, but that it approaches more nearly to chronic inflammation elsewhere in the body. Chronic gonorrhœa is divisible into two forms, according to its cause: (1) cases resulting from a spot of local irritation or granulation; (2) cases resulting from stricture.

Cases of the first class occur as follows: A patient presents himself giving a history of gonorrhœa some time in the past,—it may be months or years before. If the acute attack took place within the year, then there may be a constant discharge, more or less profuse, coming from the meatus. This discharge may be quite thick and mucoid, or thin and watery; it is generally more or less sticky, and is very apt to glue together the lips of the meatus during the night, so that in the morning they require to be pulled apart. As to color, it may vary from a bluish hue to almost complete transparence. If such cases be examined with a

bulbous-pointed instrument, it will be found that, as the instrument passes over a certain part of the canal, the patient will complain of pain. If the pain be quite sharp, and on withdrawing the instrument a little blood be found upon it, it may be affirmed with certainty that there is a small spot of granulation at the point where the pain was felt, and that the passage of the instrument caused them to bleed a little. This spot of granulations is the cause of the continued discharge, and until it is removed the discharge itself will continue, in spite of everything. Our treatment, therefore, is to be directed to this one spot, with the object of curing it; and this once accomplished, the trouble will soon cease It is understood that there is no stricture at this point or in any other part of the urethra, for in that case it comes under the second division of our subject, to be referred to later on.

Treatment.—The agent to be employed in the treatment of this affection is galvanism, and the method of its application is as follows: For the urethra the ordinary bulbous-pointed sound-electrode should be used, as is furnished by all the standard electrical-apparatus makers to-day. Care should be taken that the instrument has a blunt point, else it may irritate the urethral wall, especially while the current is flowing. The external electrode should be a flat sponge, applied to the skin anywhere in the neighborhood of the genital organs, either on the abdomen or on the inner surface of the thigh. The depth of the point of irritation having been carefully noted, the urethral electrode is introduced up to this point. The flat sponge-electrode being in position, the current is gradually turned on until a strength of 5 milliampères is reached. The electrode is now moved up and down so that the metallic bulb passes back and forth over the sensitive spot, and the whole of it is submitted, in turn, to the action of the electric current. This is continued for two minutes, and then the current is gradually reduced to zero again. Treatments may be given every four days. Length of sitting and strength of current may be gradually increased, until 10 milliampères are given for five minutes. In the writer's opinion, this is the strongest current that should ever be passed through the urethra; although he is well aware that 25 and even 40 milliampères have been recommended by different authors. At least ten treatments should always be given in a case of this kind, no matter if the discharge does stop after the first few sittings. Gleet of long standing is always prone to return, and it is this tendency of the disease which the final treatments are intended to guard against.

THE USE OF ELECTRICITY IN OBSTETRICS; GALACTORRHŒA; SORE NIPPLES.

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NEW YORK.

The Use of Electricity in Obstetrics.

In treating of the subject of electricity in obstetrics, I am well aware that many, who have already made important and commanding positions for themselves in the ranks of our profession, may say that they have successfully combated the pathological conditions connected with the puerperal state without resorting to their batteries, and that they are loth to part from traditions which have already served them well in the past. To them let me state, thus early in the consideration of the subject, that my plea for its more extended use is not to supplant other and long-tried methods of procedure which they are accustomed to resort to, but to bring to their aid a new and useful adjunct, that the desired happy termination of their cases may be the more easily accomplished and the comfort and convalescence of their patients promoted. It would be folly for me to lay down here methods to be used in all of the perplexing situations the accoucheur may find himself placed in, for experience has shown that we still have much to learn in our art. But if any advances in successful results of some of those trying positions can suggest themselves to the busy obstetrician, and help him out of his difficulties, by the use of the battery, my labor in formulating these notes will be well repaid. To accomplish this, I have divided the subject into the following component parts, each of which will be treated in its turn :—

1. Development of the female organs of generation.
2. Conception and fecundation.
3. Exaggerated symptoms and pathological conditions of pregnancy. Nausea and enuresis. Hysteria. Insomnia. Pain. Headache and backache. Mania. Melancholia. Anæmia. Disorders of circulation.
4. Threatened abortion and miscarriage.
5. Abortion and miscarriage.
6. Precipitate labor.
7. Atresia from rigidity of the os.
8. Inertia uteri.
9. Atony in third stage.
10. After-pains.
11. Accidental hæmorrhage.

The development of the female generative organs must naturally suggest itself as the starting-point of this subject, and these organs are divided into (1) the external parts, consisting of the vulva and vagina; and (2) the internal parts, consisting of the uterus, Fallopian tubes, and the ovaries. For the minute anatomy of each of these the reader is referred to Gray and Quain, as more than a brief notice here would seem uncalled for. The combined and perfect action of each part, in its relations to each other organ of the grand system, can be easily recognized as a necessity to the successful completion of parturition, and to enable it to faithfully perform its functions the proper and normal development is essential. The vulva, consisting, as it does, of the mons veneris, labiæ, nymphæ, clitoris, and hymen, is seldom the cause of trouble, as regards development, and the marriage state itself is conducive to stimulation and possible growth of the parts named. For the under-development of the external organs but little can be done; but it sometimes happens that an over-development of the clitoris is a serious mechanical obstacle to the act of copulation, and, in such cases, either surgery or the galvano-cautery should be called into requisition. The choice of these two methods for the removal of the hypertrophied organ, it seems to me, should be the latter, as by this means the severe hæmorrhage caused by the severing of the multitudinous blood-vessels in that region is done away with and a troublesome complication saved.

In the consideration of under-development of the uterus, tubes, and ovaries, occasional cases of entire absence of one or all of these organs have been met with, and any attempt at relief for such conditions must be hopeless. But where any or all of them exist in an infantile or rudimentary state, some relief may be found in the stimulation to growth. The presence of amenorrhœa at puberty is usually the first symptom to attract the attention of the patient's family, and a physician's services are called into requisition. The vulva and vagina having been found normal, and a small uterus being present, my habit is to resort to stimulation of it, and for this purpose I have used the faradic current from the long, fine wire spool, as strong as the patient can bear it without actual pain, for ten minutes, three times weekly. When it is possible, I use the flexible bipolar electrode of Apostoli, or that of Gunning, in the uterine cavity. Gunning's electrode consists of a catheter-covered flexible rod with a metal tip; this is pushed through another hollow catheter with a metal rim, to which runs, from the socket at the other end, a fine wire. As the inside one is about two inches longer than the outside one, the current, one wire having been converted to each part, must go from the metal tip to the metal rim of the other, and the distance apart can be regulated by the depth of the canal. The interpolar action is thus brought into play, and a slow stimulation to the development of the uterus will often result.

It occasionally happens that one ovary—or both—fails to perform its

functions, and on examination per vagina or rectum (with the other hand on the abdomen) a small, almond-shaped ovary may sometimes be mapped out. The patient has probably suffered from hysteria and neurasthenia, which will also help us in our diagnosis, and central galvanization (described elsewhere) and nerve-tonics will be of great assistance. In addition to this I place against the undersized organ the conical-tipped, bipolar, vaginal electrode of Apostoli, and by means of the faradic current, used strong enough to be just short of actual pain for ten minutes, three times weekly, I have been rewarded by increased growth and functional action of the organ, and an effort at menstruation.

For abnormally small tubes, a condition I have never met with, there appears to be little, if any, relief; and as this condition could only be verified by an opened abdomen, removal of the ovaries, even if they be normal, would seem to be the only rational resource; for a hæmatoma or hæmatocele would be nearly certain, were there no outlet for the catamenial flow. The attending physician will often be consulted as to the advisability of marriage with such conditions existing, and his duty is clear in giving a decidedly negative answer to such inquiry, should he see any barrier to the successful accomplishment and completion of parturition.

Conception or Fecundation.—For the proper accomplishment of this function, normal-sized and normal-acting organs are absolutely essential; and it seems hardly necessary to say here, that, given these, pregnancy may not follow,—never losing sight of the proper action and fruitfulness of the male. In all the field of gynæcology and obstetrics, there is no state more annoying to patient and physician than sterility; and the fortunate man who relieves such a condition may flatter himself that his fame will be sounded far beyond his ken. The list of causes of sterility and the treatment of them would cover far more pages than are allotted to me; the treatment of many or all may be found elsewhere in this work; but, in general terms, any condition of the vulva, hymen, vagina, uterus, tubes, or ovaries that interferes with coitus, the reception of spermatozoa in the external os, through the uterine canal and Fallopian tubes to the ovaries, the successful fecundation of the ovum and its return to the uterine cavity, may be called a cause of sterility. But certain it is, that if the patient menstruates normally, and suffers no pain or more than discomfort during the act of coitus, impregnation should take place. There are still a class of cases that seem to resist impregnation, all organs being normal in both male and female, and it is with them that I shall deal. In such cases I have usually found functional activity of the genital system impaired, and, all other causes having been found wanting, I direct all my efforts to renew healthy secretion and action of each organ, and I pin great faith upon central galvanization as a means to a successful end. In addition to this I prescribe iron, strychnia, and phosphorus, and, if possible, sea-bathing. If the inertia

of the organs of fecundation continue, I stimulate moderately the uterine activity by the use of bipolar intra-uterine applications of the faradic current, used daily for ten minutes. It seems to have a very happy effect in bringing an increase of circulation temporarily to the part; and I prefer it to the galvanic current locally, first, because we have no astringent effect of the positive pole on the natural secretions of the endometrium, and, second, because we have no relaxation of it, as caused by the negative. But these means are, of course, useless as long as an unhealthy condition or mechanical obstruction (such, for instance, as exists by a flexion or growth) exists; and I can only urge upon the attendant the most careful observation in forming his diagnosis, lest some abnormality be overlooked, and failure result after following the above plan of procedure.

Exaggerated Symptoms and Pathological Conditions of Pregnancy.—The patient having become pregnant, our attention is next called to the exaggerated symptoms of her condition, when demanding interference. And let me state most emphatically that, being sure or even suspicious of the presence of a fœtus in the uterine cavity, that belief should be the danger-signal as far as throwing a current of electricity through that organ is concerned; for nothing is better proven, in the history of electro-therapeutics, than that the current, be it galvanic, faradic, or static, thrown through the fœtal membranes, will produce death and possible expulsion of the sac and contents. Of great use to us is this fact in the conservative treatment of early extra-uterine pregnancy; but as we are not dealing with that condition here, it is most distinctly our duty to keep our current away from the gravid uterus. One condition that has complicated pregnancy, sometimes to an alarming extent, especially after having borne children frequently and close together, is that of *anæmia.* So great has been the strain upon nature that, in some cases, collapse and a fatal issue seem imminent. But, unless abortion be demanded imperatively to save the mother's life, our endeavors should be to build up and repair the overworked economy, and for this purpose I recommend moderate and gentle exercise, fresh air, nutritious food, and the use of the bitter tonics, in combination with iron, arsenic, and strychnine. Quinine and all bark preparations should be avoided, as their unquestionable effects upon the uterus and their tendency to produce abortion should not be lost sight of. A mild faradic current of quantity (through the coarse coil) given through the hands will also prove of service in promoting healthy action of the tissues, and will tone up the nervous system in a way surprising to those who have not hitherto called it to their aid. It also acts beneficially by tending to improve impaired circulation due to sluggish action of the heart, and hastens the blood on its course through the vessels and tissues.

Another most troublesome condition is *hyperemesis* in pregnancy. It is liable to make its appearance any time after the sixth week, and so

completely may it exhaust the patient that artificial abortion seems to offer the only chance of saving the mother's life; for she cannot retain sufficient food to supply her own economy, much less that of the fœtus too. Extreme cases of this affection are, fortunately, rare, and many are relieved by remedies administered internally. There is hardly a preparation in the materia medica which has escaped laudatory reports as to its efficacy in nausea of pregnancy; and yet they have been discarded, after a time, in disgust. Personally, I have been well satisfied with the action of ingluvin, minute doses of calomel, and by the use of the mild faradic current of tension, applied directly through the stomach, the negative flat sponge being upon the back and the positive over the epigastrium. By this means the already irritated pneumogastric nerve is quieted, and a sense of relief and comfort follows each application, which, to the exhausted patient, is an inestimable blessing. The effect of this treatment is the more marked if accompanied by regulated bowels, for the pressure of the enlarged uterus upon the intestine tends to cause constipation, and its effect is plainly noticeable on the stomach.

Hysteria in pregnancy is another condition which may be found most annoying to the patient and her family, as well as the physician. Lusk has shown that there is a loss of red blood-corpuscles and albumen during pregnancy; and when it is remembered that the former carry oxygen to the tissues, already overtaxed by the general drain upon them for the support of fœtal life, and their presence is rendered the more necessary thereby, it can be readily understood that anæmia and, consequently, neuralgia, hysteria, and even *mania* should exist. But it rarely happens that the removal of the irritating cause is called for by the severity of the symptoms; for much can be done by the proper use of tonics, change of air and scene, and by central galvanization and faradism, with the idea of increasing retrograde metamorphosis, and also acting as a sedative to the irritated nervous system. The same treatment will also be indicated for sleeplessness, and consequently only mild currents are called for, and are best given at bed-time.

Threatened abortion or miscarriage may sometimes be controlled by electricity, for, strange as it may seem to many, the force used to produce uterine contraction and dilation can also be made to check it, by its sedative action on irritated nerves. In the *American Journal of Obstetrics* for April, 1885, there are three cases of threatened abortion reported by Dr. W. T. Baird, where hæmorrhage had made its appearance when he saw them. The faradic current was used, and applied through an insulated vaginal electrode against the cervix, and a flat sponge-electrode was placed upon the lumbo-sacral region, for ten minutes.

My choice for quieting an irritated uterus is the conical-tipped carbon electrode of Apostoli placed against the cervix, and a very mild

faradic current used. It seems to me that it is a safer proceeding than the other, since the current does not traverse the uterine body, and can, therefore, not be harmful to the fœtus.

Abortion and Miscarriage.—There are so many ways of destroying fœtal life and causing the uterus to expel its contents and enveloping membranes by the electric current that it is hard to decide which is the best. There are three things to be sought, in producing an abortion, viz.: death of the fœtus, expulsion of it and its membranes, and subsequent contraction of the uterus. It is a well-known fact that any shock of electricity causes death of the fœtus, probably by paralysis of nerve-centres, if transmitted directly through the fœtal sac, and to this circumstance is due the excellent effects in treatment of extra-uterine pregnancy; but any discussion on that subject will be found unnecessary here, as it is so ably handled elsewhere in this work.

Precipitate Labor.—If, from any cause, it has been found necessary to empty the uterus, the proper course to pursue is as follows: Having douched the vagina with an antiseptic solution, an intra-uterine bipolar electrode is introduced as far as possible into the canal of the uterus. The presence of it alone, either as a foreign body or as a means of rupture to the fœtal sac, would probably be sufficient to cause expulsion of the fœtus; but a faradic current connected with this electrode would not only destroy fœtal life, but cause contraction of the uterus, thereby expelling its contents and leaving no relaxed organ to bleed afterward. The monopolar electrode, introduced in a similar manner, with its fellow upon the abdomen, would also produce similar results, but would cause more pain. An interrupted galvanic current will do the work equally as well as the faradic, if applied in the same manner. The method of applying one pole upon the abdomen and the other upon the sacro-lumbar region, while pretty sure to destroy fœtal life, is not to be recommended, since it often fails to expel the fœtal mass and is apt to cause serious trouble by its retention, leading to mortification, absorption, and septicæmia. One case of that kind occurs to me at this moment, the patient having applied the current to herself for delayed menstruation. She gave a history of having sat a whole morning with the poles on back and abdomen, and a faradic current as strong as she could bear was passed through the uterus. Becoming frightened on the fourth day after, as the flow had not made its appearance, she sent for me to relieve her pain; on my arrival I found she had had a chill that morning, followed by a high temperature, which was then 104° F. Of course, there was only one thing to be done,—to empty the uterus by curette,—which I did, and brought away a decomposed fœtal mass of about the fifth week. The uterus was washed out and packed, the patient put to bed, and she made an uninterrupted recovery. The use of the current through the abdomen, for any purpose whatsoever, by the laity, or any but an experienced physician, is a practice which cannot be too forcibly emphasized as

being extremely dangerous, and serious results may follow its employment if used improperly. Of course, its use and fœticidal properties are never to be sought except to save the life of the mother, and that necessity should always be the result of at least two physicians' judgment.

After-Pains.—In treating this subject, namely, the pains caused by the contraction of the empty uterus to its original size and shape, there is little use for the electric current; for nature has established this means of restoring the uterus to its normal proportions, and the pains are due to normal action; consequently their presence is a favorable sign, and only when they are excessive and beyond the endurance of the patient do they need interference. They rarely last more than three days, and may be controlled by the use of sedatives, after which the faradic current may be used, both poles being applied externally on the lumbar region and abdomen, the idea being to hasten through the condition giving rise to them.

Inertia Uteri.—The refusal of the pregnant uterus to actively do its share toward delivery, or *inertia uteri*, is certainly one of the most annoying complications which the accoucheur is called upon to deal with; and the condition is further complicated by the extreme difficulty of exciting proper action without detriment to the fœtus. The use of ergot here, in view of possible retention of placenta, hardly seems advisable, and yet has been recommended, in some instances. Sometimes the faradic or galvanic current, applied bipolar intra-vaginal, tends to stimulate uterine activity by bringing an increase of blood to the part; but the current selected should never be passed through the parturient uterus itself, for fear of harming the fœtus.

Retention of Dead Fœtus in Utero.—This condition, while sometimes extremely uncertain of diagnosis, is most important, for, as soon as fœtal life is extinct, the mass, with membranes and placenta, becomes a foreign body, and one which is most apt to undergo putrefactive changes; its expulsion, then, becomes a matter of immediate necessity, and often is recognized too late. If no air reach the dead fœtus, mummification, calcification, or fatty degeneration may follow; but once fætal death is proven (for the symptoms of which the reader is referred to the text-books on obstetrics), the uterus should be emptied at once and its cavity washed out antiseptically.

Any of the recognized methods of exciting uterine action will bring about the desired object; but the use of the flexible, bipolar, intra-uterine electrode of Apostoli is a safe and sure means, when connected with the faradic current, and is especially easy of administration, since no care to preserve the life of the fœtus is necessary.

Post-partum Hæmorrhage.—Of all the many complications which the accoucheur may be called upon to combat with, none, perhaps, creates the alarm that post-partum hæmorrhage does; its appearance is feared by all who have once been unfortunate to meet with it, and

any means of controlling it cannot fail to be welcome to the obstetrician. When we stop for a moment to consider the tremendous relaxation of pressure upon the uterine vessels after labor has passed the delivery of the placenta, especially in cases of multiple conception, the wonder is that we are not more often visited by it. So sudden and fierce is its onslaught upon the already weak and overtaxed patient that, unless ready and prepared to check it, catastrophe is sure to follow. Nature has, indeed, made wonderful provision against it, by the arrangement of muscular fibres through which the arteries pass on their way to the cavity; and when these contract, as they should do, after the delivery of the placenta, sufficient constriction is afforded to prevent accidents. But when a condition of muscular *atony* exists, due either to overdistension (as I have mentioned), collapse, or some structural change in the uterus itself, preventing its proper contraction, we are called upon to deal with a most alarming state of affairs, and one to be most carefully guarded against by every means known to science.

The use of ergot has certainly proved to be of the greatest value; the objection to it, however, is that it takes some valuable time to make its effect apparent. This may be shortened by its hypodermatic application, but the possibility of subsequent abscess should not be entirely lost sight of. The value of firm and prolonged pressure upon the empty uterus, through the abdominal wall, by the hand, is certainly the best preventive means at our command, and not until the well-known "billiard-ball" appearance is distinctly apparent to the touch can the attendant relax his close watching.

In spite of all precautions, however, dangerous bleeding is, unhappily, an occasional follower of labor, and attention must be immediately directed to contracting the uterus by any means at our command. The patient should be laid flat in bed, the pillows being removed and the hand introduced into the uterine cavity, search being made for scraps of placental tissue, which should be gently separated and removed. The presence of the hand itself, acting as a foreign body, will generally cause contractions, and will often bring about cessation of hæmorrhage without other means. The hot douche, ice in the vagina or uterus itself, perchloride of iron, and hot vinegar are all of great value in stopping bleeding, and flagellation with a cold wet towel has been strongly recommended.

But, of all means, none, it seems to me, can surpass the use of the faradic current, which should be applied by the bipolar intra-uterine electrode, if possible, or even through the uterus, the electrodes being placed upon the lumbar region and abdomen. It cannot fail to bring about uterine irritability, and its contractile effect upon muscular tissue around and in the walls of the relaxed and torn vessels stands in good stead. If applied by the intra-uterine method, the presence of the electrode itself must act as a foreign body and produce contractile efforts to expel it, provided the patient has not collapsed too far.

It is needless to remark that all these procedures should be done with strict attention to antiseptic precautions and surgical cleanliness, for the raw surfaces of the uterus are in just the condition to absorb any foreign matter of harmful nature. The small space required and reasonable cost of a good faradic machine also render it a valuable addition to the accoucheur's outfit, and a large flat electrode may be easily improvised from a wet towel folded to any desired size and connected to one or both wires by a safety-pin.

Galactorrhœa.

The secretion of more milk than is required for the sustenance of the child is a condition occasionally met with, and may be most annoying to the mother, as the flow of milk is continuous, soaking through the clothing and dribbling down in a manner that precludes the patient's appearance outside her room. It may continue after the child has been weaned, and, aside from the inconvenience of the flow, it is a severe drain upon the constitution of the mother, and exhausts her strength.

On its appearance nursing should be stopped, and small doses of the iodide of potassium should be given at short intervals, alternating with belladonna; pressure upon the breasts is also of use. The use of the mild faradic current around, but not through, the breast would also tend to diminish the flow of blood to them, and consequently lessen secretion.

Sore Nipples.

This term is one generally applied to erosions and fissures of the nipple,—conditions which are extremely painful to the mother, and are most obstinate in their cure, owing to constant irritation produced by suckling. It is not uncommon during the beginning of lactation, especially in primiparæ, to have one or more small vesicles form, which, after rupture, produce erosions, and which render the milk unhealthy. If the breast can be given rest for two or three days, a new formation of epithelium appears under the crust or scab, and the case does well. The treatment depends largely upon absolute cleanliness and the use of some mild astringent lotion, such as any of the lead lotions, tannin, etc., care being taken to carefully wash the nipple if found necessary to use that breast for nursing. Rubber nipple-shields have been recommended, but the child often refuses to nurse through them. My own practice is to have the nipple bathed three or four times daily with the white of raw egg, and, while wet, sprinkle powdered boracic acid on it. If the child has sprue, its mouth should be carefully washed out with a weak solution of borated soda before nursing.

Fissures of the nipple are much more obstinate to cure than erosions, and are excessively painful to the mother. They are often extremely minute, and may cause high fever. The treatment of them

consists in touching them with either the hard, dry pencil of nitrate of silver or a weak solution of it (not over gr. xx–℥j), as a strong solution may cause excessive excoriation of the tender epithelial covering. Barker has strongly recommended the use of the compound tincture of benzoin; this is said to be painful upon the first application, but soon can be easily tolerated. The only use for electricity in this condition would be the application of the faradic current, as in galactorrhœa, around the breast, not through it, the idea being to lessen the secretion of cholesterin, which forms a crust on the outside of the nipple, and which tends to increase the fissure. Belladonna ointment also assists in drying up the flow of cholesterin.

ELECTRICITY IN DISEASES OF CHILDHOOD.

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THE applications of electro-therapeutics in childhood, as in adult life, are twofold,—surgical and medical.

SURGICAL INDICATIONS FOR ELECTRICITY.

Electricity may be employed surgically in either of two ways,—for the electro-cautery or in the form of strong galvanic currents. The end to be reached in both cases is the same, namely, the cauterization and consequent destruction of morbid tissue.

Electro-cautery.—With the use of the electro-cautery the electric current does not directly affect the body of the patient, but only indirectly, as it serves to render incandescent a platinum loop, whose burning properties may replace the cutting properties of the knife. The electro-cautery does not differ essentially from the Paquelin thermo-cautery; the choice between the two instruments is determined by the relative convenience of the one or other contrivance for attaining the same end.

The essential part of the electric cautery is a thread of platinum, which, like a similarly narrow thread of carbon, becomes red-hot when traversed by a galvanic current, owing to the great resistance which is offered by so narrow, yet so perfect, a conductor. The thread must always be bent in a loop, inasmuch as it is essential that the circuit be completed. The loop is sometimes large, and used to encircle a pedicle, which it cuts through after the fashion of the cold snare, though with more facility. At other times the loop is compressed so that it may be used like a knife; it is then "voluminous and cylindrical." (Verneuil.) The electro-cautery may, of course, be used for children in any of the operations common to them, and in adults for which this method may be desirable. Among these, however, are some which are more frequent or more conspicuous among children, namely, tracheotomy, the removal of nasal polypi, naso-pharyngeal tumors, or the tonsils, the treatment of the tonsils by ignipuncture, and the destruction of nævi.

Tracheotomy.—In 1870 Amussat, by means of the galvano-caustic loop, opened the trachea of a child to remove a pebble which had lodged in it a month previous. The method employed was peculiar, and has not, that I know, been imitated by any subsequent operator. Amussat passed a curved needle carrying a double platinum thread into the trachea, directly through the skin and other superjacent structures,

and then emerged about two centimetres above the point of entrance. In this way two centimetres of the trachea were embraced by the platinum loop. The two ends of the loop were then connected with the two poles of a galvanic pile, and the intermediate loop heated by the current and drawn through the entire mass of intervening tissue. As soon as the trachea was opened the child coughed and expelled the foreign body. The operation did not cost a drop of blood. Five weeks later the wound had cicatrized, and the child was cured of the pulmonary inflammation which had been excited by the foreign body.[1] In 1872 [2] Voltolini, for the first time in Germany, opened the larynx and trachea by the galvano-cautery, in order to remove a polypus from the glottis. In 1873 Verneuil reported to the French Academy of Medicine his first case of operation by this method,—an operation apparently performed in ignorance of Voltolini's. This first patient of Verneuil's was a man suffering from syphilitic laryngitis, supposed at the time to be tubercular, and threatened with immediate death from œdema of the glottis. The operation was quite successful, as also a second, where a dangerous spasm of the glottis had been induced by tetanus. Three other cases of tetanus so operated died, as also a child with croup, operated by Bourdon, who reports the whole six cases in the memoir already quoted.[3]

Thus, although tracheotomy is pre-eminently an operation for children, the galvano-caustic method was originally used mainly for adults, and the indications for its selection found principally in them. The great advantage of the method—and this is sometimes immense—is that it avoids hæmorrhage; and in the conditions for which adult tracheotomy is most often demanded,—œdema of the glottis, neoplasms, or, according to Verneuil, the asphyxia of tetanus,—hæmorrhage is liable to be an alarming feature. In children it is usually more easy to reach the trachea, and to a skillful surgeon the operation should rarely offer difficulties or be attended by serious bleeding. However, tracheotomy is, or was, before the introduction of intubation, indicated in many cases and in many localities where it must be performed, if at all, by physicians who are not especially skilled surgeons, and who are liable to be confused and startled by a profuse gush of blood from the throat of a child already, perhaps, lying at the point of death. Moreover, the varying position and varying degrees of engorgement of the thyroid gland, and the difficulties offered by the short and fat little neck so often found in children, are serious considerations even for the most experienced. The possibility of operating without losing a drop of blood is, therefore, an unquestioned advantage in the galvano-caustic.

On the other hand, the galvanic loop is rather more difficult to

[1] "De la Trachéotomie par le Galvano-cautere." Emmanuel Bourdan, in Archives Gén. de Méd., January, 1873.

[2] Berlin. klinisch. Wochensch., 1872, No. 41.

[3] Archives de Médecine, 1873.

manipulate than the bistoury. The first and, on the whole, the greatest inconvenience of the operation lies in the difficulty of keeping the incision exactly in the median line. This is somewhat harder to do with the cautery than with the knife. Trousseau's precaution, to mark the line of incision with ink, may be used. The tissues must be penetrated slowly. Verneuil occupied about five minutes for the whole operation. In children the trachea can be entered much more rapidly. If the soft parts are properly condensed by the heat of the cautery, they will retract on either side; although Bourdon makes the singular remark that in adults the tissues swell so that the trachea seems to lie at a greater depth than normal. When the trachea is exposed the instrument must be made to penetrate the first intercartilaginous space, then divide the tracheal rings from above downward. This is much easier than to cut directly from without inward. The loop must be inclined a little, so as to avoid touching the posterior wall of the trachea.

Bourdon observes that at the moment the trachea is opened, and when by the ordinary method the operator is accustomed to hear a sudden hissing noise, and a paroxysm of coughing occurs which expels blood and mucosities from the trachea, he will be astonished to find a perfect calm,—so much so that he may fear that he has made a false passage. This calm is perhaps due to the fact that nothing falls into the trachea to excite a paroxysmal inspiration; and this circumstance is certainly a favorable one, and an additional advantage in the method. The severed halves of the trachea must be held apart by retractors during the insertion of the cannula, as in the ordinary operation. The introduction of the cannula is rendered easy by the dryness and retraction of the soft parts, and the distinctness with which the trachea appears at the bottom of the wound.

Electrolysis for Hypertrophied Tonsils.—The advantage of avoiding hæmorrhage, alleged as the important reason for using the electro-cautery in tracheotomy, has also been urged in favor of employing the same instrument as a substitute for the knife or the guillotine to amputate hypertrophied tonsils. The platinum loop is adjusted around the protruding portion of the tonsil, and, when in place, is heated to redness by the passage of the current, and then slowly tightened as it is drawn through the tissue. This is thus burned through and cut through at the same moment. Knight[1] approves of the galvano-caustic loop, but thinks it may as well be reserved for exceptional cases, where hæmorrhage is especially threatened on account of vascular anomalies or a hæmorrhagic diathesis, or where the complete excision is impossible, or where the patients, or the parents of the patients, refuse to allow a cutting instrument to be used. Delavan, on the other hand, asserts that the dread of hæmorrhage is superfluous, since there is no case of fatal hæmorrhage after tonsillotomy on record. Elsberg, indeed, reported 11,000 tonsil-

[1] New York Medical Journal, October 12, 1889.

lotomies without a fatal case, but including several alarming hæmorrhages.[1] But Hoyle Butts reports 46 cases of alarming tonsillar hæmorrhage where three times the common carotid was ligated, and where 3 other cases did prove fatal.[2] Only 2 cases on this list were children, however; 1, a boy of $3\frac{1}{2}$; 1 a girl of 7,—a hæmophile. Delavan's second objection to the galvanic loop is a greater difficulty of application for the operator and more pain for the patient. This writer even claims that diphtheria of the stump occurs more frequently when the tonsils have been removed by the cautery than by the knife, which is a strange assertion, and must be based on quite accidental personal experience, for the eschar left by the cautery should certainly be less prone to infection than the open wound after cutting. The greater difficulty in manipulating the galvano-caustic loop is, however, a serious objection to its use for children. To secure the principal advantage of this method, namely, the avoidance of hæmorrhage, it is necessary that the loop be heated to only a dull-red heat and allowed very slowly to cut its way through the tonsil. The pain of the process can be sufficiently diminished by the previous application of cocaine to render the operation quite tolerable for adults; but for children it is essential to operate as quickly as possible: the loop must be guided by the eye, while the amygdalotome can be manipulated under the guidance of the finger alone; finally, an anæsthetic can hardly be used with an incandescent loop, and for children an anæsthetic is generally necessary. Therefore for them some form of amygdalotome is preferable unless, indeed, the known existence of the hæmophilic diathesis makes the fear of hæmorrhage the paramount consideration. But in such cases operations on the tonsils, as all other surgical procedures, are avoided unless absolutely necessary.

Ignipuncture.—The platinum loop is used not only to remove the tonsils, but also to treat their chronic inflammations by burning out their diseased crypts. The compressed loop, heated to redness, is plunged into the mouths of the distended crypts, as these open on the inner surface of the tonsil, piercing this surface at three or four points at each sitting. The operation should be repeated either once or twice a week.

Surface cauterization of the tonsils is not new. According to Valat, it was employed as early as 1252 by Brunns, a surgeon at Padua, to prevent the tonsil from growing again after removal by the knife.[3] The burning was then, of course, done with the actual cautery. This same method has been used in modern times by Krishaber. According to St. Germain,[4] however, this superficial cauterization of the tonsil is of little use, and the treatment requires to be indefinitely prolonged. For

[1] Transactions American Laryngological Association, 1881.

[2] New York Medical Record, July 1, 1893. Thirty-one of these cases had previously been reported by Wright in the same journal, August 30, 1890.

[3] Valat, "Traitement de l'hypertrophie des amygdales par l'ignipuncture," Gazette des hôpitaux, 1888.

[4] Revue des maladies de l'enfance, 1884, ii, p. 520. Roth, Lancet, February 16, 1889.

the true electrolytic method of ignipuncture, however, St. Germain is an enthusiastic advocate. He plunges the compressed galvano-caustic loop into the centre of the tonsil to the depth of a centimetre. Four days later the tonsil will be found shriveled to one-third of its former size, and after a third sitting—thus in about eight days—the tonsil will often be of quite normal proportions. The author uses a special mouth-gag for the operation. Potter[1] finds five sittings necessary, on an average, four to seven days apart. He claims that under cocaine the operation is nearly painless. Wright[2] has used the method in about 1200 cases, but not in children under 12, for whom he prefers tonsillotomy. Children will not submit to more than one or two sittings, and after these there is still left a ragged mass of tissue,—a lodging-place for secretions and for *débris* of food. But in adults ignipuncture is most satisfactory; about seven sittings are required. Ouspenski,[3] however, begins to use ignipuncture at the age of 10, altogether discarding tonsillotomy. Of fifteen cases treated, in five the tonsils contracted entirely to a normal size; in ten the hypertrophy was much diminished.

From the details given by so many operators, who are all precise in stating the length of time required for effective treatment, it is difficult to understand why the opponents of ignipuncture should assert that the treatment must needs be prolonged during many weeks and even months. Nevertheless, even the advocates of ignipuncture do not advise it for young children. It may be added that the very large, pale, sclerosed tonsils, often found in lymphatic and scrofulous children, are unsuited to the galvano-caustic treatment, and are removable with great ease and a minimum risk of hæmorrhage by the guillotine. The radical operation should, in fact, be performed as early as possible, in order to avert from the little patient the numerous and dangerous inconveniences resulting from pharyngeal obstruction.

There is a close pathological similarity between these sclerosed tonsils and the cervix uteri which has been left hypertrophied and sclerosed by chronic metritis. In both cases topical medication is useless, for the offending condition is not a disease, but the residual product of disease, a *caput mortui*, which cannot be modified, and must be removed.

The large fibrous tonsils are removed with especial facility either by the guillotine or galvano-caustic loop, through which they are readily made to protrude; and owing to the diminished vascularity of the tonsil, its removal is attended with little hæmorrhage, unless, by unskillful manipulation, it has been forcibly dragged up from its bed and the subjacent veins injured. Thus, the cases where complete extirpation of the tonsil is most necessary are usually those where it is most easy, and can be effected by comparatively unskilled hands.

In other cases, the tonsils, though chronically inflamed, remain only

[1] Medical News, Philadelphia, 1888. [2] *Ibid.*, p. 332.
[3] Annales des maladies de l'oreille, Juillet, 1888.

moderately hypertrophied. The child is subject to recurrent attacks of acute follicular tonsillitis, with proliferation of adenoid cells, but this has not yet been succeeded by connective-tissue hypertrophy. The microbes associated with the acute attack or their spores apparently remain lurking in the crypts, in the cheesy material into which the adenoid tissue breaks down, and from this persistence of the morbigenic agent results a constant imminence of new attacks. The heated platinum point penetrates the surface-crypts, destroys their contents and their mucous wall, and thus tends to promote an adhesive inflammation by means of which the crypt-walls may become agglutinated and their lumen obliterated. After the surface-tissue of the gland has thus shriveled and atrophied, a new ignipuncture is able to reach deeper layers of crypts, and the process of condensation is repeated. Although the complete reduction of the tonsil is only slowly effected, relief from recurrent attacks of acute inflammation is often very rapidly obtained,—partly, as already suggested, because the cautery destroys the spores of microbes which were lurking in previously-inflamed tonsillar crypts; partly, also, because it so hardens the surface of the gland as to render it a less-suitable nidus for the reception of fresh germs. It is in this class of cases that complete extirpation of the tonsils is difficult, as they do not project well beyond the pillars. As the tonsils are more vascular, hæmorrhage after the operation is more abundant. Finally, cases of this class are more numerous; hence more likely to fall into the hands of less-skilled practitioners, who might shrink from the larger operation, or to whom its opportunity might be refused; but who, by a timely use of the ignipuncture, could often avert the fibrous hypertrophy of the tonsils and special dangers incident to such condition. The ignipuncture is rendered quite painless by the previous application to the tonsil of a piece of absorbent cotton soaked in a 10-per-cent. solution of cocaine. It must be admitted that all the advantages of ignipuncture of the tonsils obtainable by the galvano-caustic loop can be secured by the platinum points of a Paquelin cautery; so that the discussion of this subject only touches incidentally upon the electro-therapeutics of childhood. Adenoid growths of the vault of the pharynx are best removed by the curette or thimble.

Nasal Neoplasms.—Obstruction of the anterior nasal passages dependent on polypi, or on hypertrophy of the inferior turbinated bones, may be very successfully relieved by the galvano-caustic loop, which encircles the neoplasm cold, is heated *in situ*, and, by gradual constriction, bloodlessly removes the new growth. Pain is greatly diminished, though not entirely averted, by the previous application of cocaine.[1]

Electrolysis.—Many years ago Nélaton proposed electrolysis for the destruction of naso-pharyngeal tumors, whose removal by the knife is so often endangered by hæmorrhage, or followed by pneumonia, due

[1] Baker, British Medical Journal, 1888.

to aspiration of fluids to the lungs during the operation.[1] Küttner reports two successful cases of nasal polypi treated by electrolysis. A current of 20 to 25 milliampères was passed for five minutes into the tumor, which shriveled entirely after four applications in the one case and after six in the other.[2] Campbell[3] relates an interesting case of electrolysis, in a man, for a large growth on the left turbinated body. Both needles were inserted into the mass, at a distance of four lines from each other. A current of gaseous bubbles formed around the negative needle, which condensed into a watery fluid. This fluid, claims the writer, was transferred by electrical osmosis from the positive pole, where the tissues were left black and shriveled, and black scales of peroxide of iron formed from oxidization of the steel needle. After twenty minutes' application, during which the needles were shifted from place to place, the growth was entirely destroyed. "The transfer of liquid particles must necessarily produce chemical decomposition in the electrolyte, for it arrests the functional activity and nutritive movements in the cells, and with this their life necessarily ceases." Campbell reports another case,—this time in a boy of 14 years,—where three electrolytic sittings sufficed to destroy an erectile tumor, the size of a hazel-nut, in the region of the cervical glands. Two positive and three negative needles were inserted, about five lines apart, with a current varying from 10 to 40 milliampères. The application lasted fifteen minutes,—the writer claiming better results from moderately-intense currents of long duration than from stronger currents applied during a shorter time. To obtain the greatest destructive energy of the current Küttner chooses a double, or forked, electrolytic needle, combined with both poles. Küttner thinks that naso-pharyngeal tumors offer the greatest field for the use of electricity. Groesbeck has collected thirty-three cases, of which seventeen were completely cured by electrolysis and thirteen improved.[4] Notwithstanding such favorable reports and the theoretical reasonableness of the method, electrolysis for nasal growths is condemned by Voltolini,[5] Bruns,[6] Verneuil,[7] and Billroth.[8] These authorities pronounce the treatment unnecessarily prolonged and painful, and not to be compared in prompt efficacy with cutting operations, the galvano- or Paquelin cautery, or the cold snare. Here, as in several other departments of therapeutics, the question of electrolysis *versus* the knife will often be decided according to the special skill and habitual line of thought of the practitioner into whose hands the case happens to fall. And it may often be true that the same case, which in the hands of one surgeon would have done extremely well under a cutting operation,

[1] Comptes Rendus de l'Acad. des Sciences, 1864, 18 Juillet. The latter accidents, from swallowing, may generally be averted by a previous tracheotomy.

[2] "Die Electrolyse bei soliden Geweben," Berliner klinische Wochenschrift, 1889. See also Althaus: Electrolytic Treatment of Tumors. London, 1867.

[3] Phys. and Surg., Ann Arbor, 1892, p. 193.

[4] *Loc. cit.*

[5] Die Krankheiten der Nase. Breslau, 1888.

[6] Berliner klinische Wochenschrift, 1872.

[7] Quoted by Bruns.

[8] Wiener med. Wochenschrift, 1875.

would with another be far more safely and effectively treated by the electric current.

Electrolysis in Nævi.—The most important application of electrolysis in children's diseases is for the cure of nævi. Here, not the electro-cautery, but the galvanic current itself, is used, of a strength sufficient to be destructive. Campbell reports twenty-seven cases of nævus and thirty-five of erectile tumor,—all cured. One of two methods may be used,—the bipolar or the polar. By the first both needles are plunged into the nævus, as in the treatment of the nasal polypi just described. The needles should be of gold or platinum, one-half millimetre in diameter and three or four centimetres in length.

Maclean[1] relates an interesting case treated by this method as a preliminary to extirpation :—

The patient was 14 years old, and the nævus involved all the tissues of the cheek, extending from the nose to the ear and from the lower eyelid to the upper lip. The patient was anæsthetized by chloroform, and two fork-shaped needles were plunged deeply into the tumor. They were raised to white heat by a current of 2 volts. The current was reversed in a few minutes and the application continued for a few minutes longer. Immediately afterward the tumor seemed somewhat larger, but harder, and it gradually shrank again to its original size. After a second electrolysis the tumor became reduced to a solid fibroid mass, in which the blood-vessels were contracted or destroyed, so that the whole could be removed by the knife easily and without hæmorrhage.

Polar Method.—Althaus used the polar method, with the negative electrode exclusively attached to the needles in the tumor, the positive one on an indifferent part. Redard[2] asserts that the negative electrode leaves scars. He himself recommends that the positive electrode be connected with four needles, so arranged that these can be simultaneously plunged into the tumor, extending from its centre to its periphery. A current of 25 to 30 milliampères is required, and should be cut off before the needles are removed. The current should be allowed to flow for two to four minutes, then the needles removed and inserted in a new place, until a sufficient number of escharred tracks have been formed. The application should be repeated every six or eight days. The author has thus successfully treated thirty cases of nævus on the lips and face.

Duncan[3] cites eleven successful cases of cirsoid aneurysm treated by electrolysis, and declares it to be the best method of treatment for angiomata if the tumor is growing, if it be situated in a locality where it is important to avoid cicatrix, and if the subcutaneous part be very large in proportion to the cutaneous part of the tumor. Ashby and Wright,[4] who devote a rather long chapter of their valuable treatise to the discus-

[1] D. Maclean, Phys. and Surg., Ann Arbor, 1884, vi, p. 400.

[2] Archives of Pediatrics, 1888.

[3] British Medical Journal, November 3, 1888. See also Beard, "Electrolysis in Surgery," New York Medical Record, 1879, vol. i. This author says that the best results from electrolysis are obtained in the nævi which are elevated above the level of the skin. The method is less successful with subcutaneous tumors, or with port-wine marks.

[4] Treatise on Diseases of Children. London, 1892.

sion of nævus, also pronounce decidedly in favor of electrolysis as the best method of treatment for all forms of operable vascular tumors.

Very small and well-circumscribed nævi may sometimes be safely excised with their inclosing capsule. I have done this on an infant a few months old, where the nævus was situated on the left cheek. The edges of the resulting cavity were brought together and healed by first intention, leaving only a slight scar. There are, however, only a few vascular tumors where such an operation is feasible, or at least facile. Flat nævi are generally too diffused, and in many, either flat or prominent, the vessels entering the tumor are too large to be controlled by torsion; many ligatures are required, rendering the operation complicated, and, without great care in forestalling hæmorrhage by ligatures previous to section, hæmorrhage may occur and be formidable.[1]

It is always desirable to operate upon nævi as early as possible,—thus, while the child is still very young, and at the very time that it is important to avoid serious operations and risks of hæmorrhage. Another alternative to excision—injection of the tumor with iron, alcohol, or other coagulants—has little to recommend it, and, in spite of occasional advocacy,[2] is to-day generally abandoned.[3]

The actual cautery, whether the Paquelin or the galvano-caustic, is sometimes successful.[4] But—as I myself have had occasion to observe—the cauterization of the periphery or the surface of the tumor, which is necessarily incomplete, often seems to stimulate the development of blood-vessels adjacent to those which have been destroyed, so that, for a time at least, the tumor enlarges rather than shrinks under the treatment. The electrolytic method is free from this objection. The fine needles employed can be plunged deeply into the vascular mass, and the shrinkage of the latter is not dependent merely upon the lines of eschar formed in the track of the needles, but on the contraction of blood-vessels which occurs in the neighborhood of the positive pole of the electric current. The morbid tissue can be attacked in several places in rapid succession, or even at once, if the device be used of attaching several needles to a single electrode. Theoretically the polar method, with the anode plunged into the tumor, is much the best, because the entire action of the current is then employed in contracting blood-vessels, and in

[1] N. Davies Colley (Guy's Hospital Reports, 1879) prefers excision, and claims primary union in a large number of cases. This physician strangulates the base of the tumor with hare-lip pins or silk sutures. He relates two cases, one in a baby only 10 weeks old, where a large nævus on the back of the neck was successfully removed, without loss of a drop of blood, by the use of the pins and a rubber ligature strangulating the base of the tumor. He admits, however, that hæmorrhage may be a drawback. In the other case, a baby 9 months old, the operation was followed by an attack of erysipelas which lasted two months.

[2] Holgate (Archives of Pediatrics, 1889) strongly recommends the injection of absolute alcohol. A case is reported of a nævus cured in seven days by the injection of Fowler's solution (British Medical Journal, 1884, vol. i).

[3] Coates punctures small nævi with cataract-needle, to set up a destructive inflammation (British Medical Journal, 1883, vol. ii).

[4] Westmoreland, Atlanta Medical and Surgical Journal, 1884. Several successful cases are related. So also Owen, British Medical Journal, 1883, vol. ii.

forming the hard, black eschar characteristic of the positive pole. The cathode, on the other hand, tends to determine a congestion or afflux of blood to the tissue to which it is applied, and dilatation of blood-vessels; the eschar formed is soft and fluid. There is, therefore, a possibility of stimulating the growth of new blood-vessels in or around the tumor by the use of the cathode. Although nævi have frequently been treated, and successfully, by passing the entire current through the tumor, yet, in view of these theoretical considerations, the positive polar method is usually to be preferred.[1]

The object of the electrolytic application is, first, to obliterate the blood-vessels on the surface and on the periphery of the tumor; then to secure the formation of coagula, which shall extend backward from the point of obliteration into subjacent vessels still patent, and thus begin the obstruction of their channels. The obliteration of blood-vessels is part of the general destructive effect on living tissue caused by strong electric currents. The tissues are eroded by the acids and alkalies developed at the poles, and the evolution of these elements is itself an indication that the tissues from which they are derived have been decomposed. But, besides, the current directly kills the cells of living tissue over a certain area, and then this area of necrosis cuts off nutrient fluids from adjacent areas, and thus tends to spontaneously enlarge.[2]

The second application of the electric current should produce its primary effect at the place which was the seat of the secondary coagulum formed after the first application. From this point—the blood-vessels now being completely cauterized and destroyed—fresh coagula will form and extend still farther inward, and thus the process may be indefinitely repeated until the whole vascular mass has shriveled. In large nævi the process is necessarily slow, though ultimately completely successful.[3] In small and superficial nævi, about the size of a dollar, cure may often be effected by two or three applications. The electrolytic method has the great advantage over any form of injection that it not only, like the injections, coagulates the contents of the blood-vessels, but destroys the walls of the vessels, which the injections leave relatively intact.

While electrolysis may thus be rapidly successful with small nævi in babies, where excision is also applicable, it is equally adapted to the treatment of vascular growths which have grown so large as to have become inoperable by the knife and ligature. In the winter of 1893 Dr. Fox presented, at the New York Academy of Medicine, a young man cured, by electrolysis, of a nævus that had formerly extended over half

[1] Vigoroux, Progrès méd., 1891.

[2] Küttner, *loc. cit.* Duncan, after an elaborate analysis and classification of the different kinds of nævus, pronounces electrolytic treatment the most satisfactory. By it "both blood and tissues are decomposed into their simplest constituents." Edinburgh Medical Journal, 1885. So Hallipeau declares electrolysis the most effectual treatment. "Leçons sur les nævi," Progrès méd., 1891.

[3] "Large, deep-seated nævi on trunk or extremities may be made to slough out *en masse* by an electric current from 30 or 40 cells." Clutton, St. Thomas Hospital Reports, 1882, vol. xi.

the face. The treatment of this extensive disfiguration had been proportionately long, but not extremely painful. Only a moderate blemish, due to slight scarring, remained. Not only the difficulties caused by the size of the tumor, but also those arising from its locality, are overcome by electrolysis. The method is especially suited for nævi which involve the eyelids, or are situated near the nostrils or angles of the mouth. Nævi at the angle of the jaws, formed in the ramifications of the facial artery, sometimes grow with malignant rapidity, minute capillaries developing to large and tortuous veins and arterioles, as the vascular mass advances toward the central blood-vessels. Many years ago an infant of 2 years was presented, at a New York Medical Society, with an enormous arterio-venous aneurism covering the lower part of the face, right angle of the jaw, and extending far into the neck toward the carotid. This tumor had developed under the eyes of an attendant physician from a moderate-sized birth-mark, easily amenable to treatment, to a condition where any form of treatment was impossible, and the unfortunate baby doomed to die. The case occurred before electrolysis of nævi had been suggested; but it serves to illustrate by contrast the value of a method which, to-day, could so readily have been employed.

Goitre.—There is another form of vascular tumor to which electrolysis has been applied, namely, goitre. Dr. Duncan, whose successful cases of angiomata have already been quoted, has treated 14 cases of goitre by electrolysis, of which 6 were quite cured and 3 were still under treatment at the time of the report; 4 were lost sight of; in 1 only was the treatment known to be unsuccessful. Beard, whose article on electrolysis has been already quoted, recommended electrical treatment for exophthalmic goitre as early as 1879; but, of course, on a different principle. Küttner (*loc. cit.*) advises the negative pole for the treatment of goitre, with needles isolated until very near their tips, while the positive electrode is flat and placed on the sternum. A rheostat is absolutely necessary in order to increase the current without severe pain, and to render possible the use of strong currents, as high as 90 milliampères.[1]

Hydrocele.—Beard treated hydrocele in two children by electrolysis. The negative needle was inserted into the tumor; for it was not expected that fluid would be coagulated, but that the current would prevent secretion and determine absorption. In one case, owing to the struggles of the child, the application could only be continued a moment, but the child was cured in a few days, after the single application.

[1] See also Morton Prince, Boston Medical and Surgical Journal, 1890. Campbell, whose enthusiastic advocacy of electrolysis has been several times quoted, has treated twenty-three cases of goitre by electrolysis, of which five improved. This showing is not very favorable.

Medical Uses of Electricity.

PARALYTIC AFFECTIONS.

Apart from the electrolytic action of the galvanic current, electricity is used for children, as for adults, in a certain number of diseases and morbid conditions of the nervous system.

Asphyxia Neonatorum.—The accidents of asphyxia—either those due to narcotic poisoning or the so-called asphyxia neonatorum, which is properly an apnœa—call for prompt electric treatment. Marshall Hall is said to have been the first to suggest the electrization of the phrenic nerves as a means of resuscitating newborn children. Whenever the muscles of the body are found to be still excitable by the faradic current, the hope of arousing the contractility of the diaphragm may be entertained. In the contrary case efforts at resuscitation would be futile, and should be abandoned, or not undertaken.

In 1857 Ziemssen published a case of successful artificial respiration in a girl poisoned by charcoal-vapor. The rules for making the application in this case apply equally to the asphyxia of the newborn. The electrodes must have large buttons, so as to surely cover, on the one hand, the phrenic nerves, and, on the other hand, the branches of the cervical and brachial plexus, which are distributed to the external respiratory muscles,—namely, the trapezius, levator scapulæ scaleni, on the one hand, and to the pectorals, serati, and rhomboid, on the other. It is impossible to make the intercostal muscles contract under artificial stimulus. It is, therefore, all the more important to try to bring the auxiliary muscles into play. The head, arms, and shoulders of the child must be solidly fixed by assistants, so that the attachments on the thorax become the movable points for the muscles. A bifurcated electrode from a faradic battery should be pressed deep into the triangle between the sterno-cleido and scalene muscles, just above the clavicle, the other electrode being held against the spinal column. A weak current should be passed for two seconds. This causes a single deep inspiration. The circuit is then opened, and at the same moment an assistant presses the abdomen and its contents against the diaphragm, imitating the movement of expiration. In from one and a half to two seconds the inspiratory stimulus is repeated and the entire cyclical process continued until spontaneous respiration be established, or hope abandoned. The occurrence of cough is a very favorable symptom. The faradic stimulus must not be interrupted too soon, for it has happened, although spontaneous respirations were established, that it ceased again, after a few minutes. When, after some hours of normal breathing, the respiration again flags, it is probable that there is not merely a functional inadequacy of the respiratory centres, but some organic lesion of brain or lungs. Atelectasis will set in if the respiratory movements, though normal in rhythm, are not sufficiently vigorous; and this is very apt to

be the case with premature children, because the contractions of the respiratory muscles are feeble and because the thorax is still soft, and yields to the weight of atmospheric pressure, instead of forming a rigid cage within which a potential vacuum may be created by the elevation of the ribs and the depression of the diaphragm.

Further, the circumstances in which asphyxia neonatorum occurs are frequently such as to favor or determine intra-uterine respiration, with consequent aspiration of fluids into the lungs, by which a greater or less portion of lung-tissue is rendered impermeable to air; the child then, though temporarily resuscitated, succumbs as it might under pulmonary congestion of any other origin. In one case I succeeded in establishing spontaneous respiration, after rhythmic faradization continued over two hours. The child lived two days, but then died with the symptoms of atelectasis. Ziemssen cites five cases, in three of which faradization was permanently successful and in two the result was unfavorable. In the case of charcoal-vapor poisoning to which Ziemssen first applied the method, rhythmic faradization was kept up for eleven hours. A case of my own, an infant 2 months old, became profoundly narcotized after a few doses of Dover's powder, $\frac{1}{40}$ grain each, administered for diarrhœa. Faradization was applied over the chest,—not directly to the phrenic nerves, but simply as a general reflex stimulant. The electric application alternated with the administration of mustard baths, that seemed to act very much in the same way as the faradic current, stimulating respiration by reflex cutaneous excitation. After two hours' assiduous treatment, the child recovered and began to nurse.

Caldwell[1] relates several cases of recovery from narcotic poisoning obtained by means of thoracic electrization. In the first the child had swallowed laudanum twelve hours previously; the respirations were 9 a minute. In this case the galvanic current was used,—the positive pole placed against the outer border of the sterno-cleido-mastoid muscle, the negative pole upon the epigastrium. The current was continued for three hours. Then the respirations had risen to 18 and 20, the contracted pupils had dilated, the pulse became normal, consciousness returned, and an attack of vomiting and purging ushered in complete recovery. In the second case, an infant only 10 days old, narcotized by morphine, recovered under the use of the faradic battery. In a third case a child of 7 had swallowed a bead into the trachea. Tracheotomy was performed, the bead expelled by a cough, and the child gave one deep inspiration, but then ceased to breathe. Alcohol was injected into the rectum, and the galvanic current passed through the phrenic nerve, when the child at once rallied.

Griswold[2] notes the danger of stimulating the vagus at the same time as the phrenic nerve. But in ether, opium, and aconite poisoning

[1] Gaillard's Journal, 1880, vol. xxix.

[2] Transactions New York Academy of Medicine, 1886.

it is safe to try to stimulate the phrenic nerve, because, in the first case, the heart is not depressed, so that the pneumogastric nerve can bear a little stimulus with impunity; in the second case, the heart's action is rapid and feeble, so that it is desirable to exercise some inhibitory action if possible; in the third case, the pneumogastric is paralyzed, and would not respond to electricity. But in chloroform poisoning stimulating the vagus would readily arrest the action of an already failing heart, and therefore, to avoid reaching the vagus, the electrization of the phrenic nerve must also be avoided.

Broncho-Pneumonia Atelectasis.—Dr. A. Jacobi frequently uses general faradization of the thorax in the atelectasis which is apt to complicate the broncho-pneumonia of infants and young children. About once an hour the little patients are thus made to cry; the forced expiration is followed by an increased inspiratory effort, which tends to expand the collapsed lung. Gunter advises the same treatment.[1] It is in these same conditions that inhalations of oxygen are now so generally employed with advantage.

In using electricity to establish or restore respiration the stimulant is addressed to the nervous mechanisms which control the respiratory act. The remaining indications for electro-therapeutics in childhood are, similarly, all found in disorders of the nervous system.

Infantile Paralysis.—The most important and most frequently occurring disease of the nervous system in children for which electric treatment is recommended is antero-poliomyelitis,—the so-called infantile paralysis.[2] At the very outset of the disease electric tests are relied upon to establish the diagnosis, and, to a certain extent, to formulate the prognosis also. According to the well-known law established by Duchenne, the muscles innervated from a spinal segment affected by acute antero-poliomyelitis lose their faradic contractility, in whole or in part, about a week after the occurrence of the lesion. This fact serves to distinguish a spinal from a cerebral monoplegia, and is particularly useful in the not very rare cases where the paralysis, though spinal, assumes a hemiplegic form. In the pseudoparalysis of syphilitic osteitis, although the loss of voluntary power be apparently complete, the faradic contractility of the powerless limb is preserved. In the paralysis after diphtheria and other infectious diseases, the faradic contractility is also diminished or lost,[3] since these depend sometimes upon a multiple neuritis,[4] sometimes upon a poliomyelitis differing from the common in-

[1] Centralblatt für Chirurgie, 1880.

[2] "After tabes, poliomyelitis anterior offers the most frequent indication for electrical treatment." Ziemssen: Electro-therapeut., 1887. The learned writer must mean, "the most frequent among organic diseases"; for, certainly, the indications for electric treatment are much more numerous among functional than among organic diseases of the nervous system.

[3] Bartholow: Medical Electricity, p. 171. Simon (Union Médicale, 1879) asserts that electric contractility is preserved in diphtheritic paralysis, but he probably means the response of muscles to direct excitation.

[4] Starr, "Multiple Neuritis" (Middleton Goldsmith Lectures), New York Medical Record, 1887.

fantile paralysis only in its origin. In these toxic paralyses, however, the direct faradic excitation of the muscle will cause contractions, even when there is no muscular response to the electric stimulus of the nerve. The same is true of poliomyelitis in the earliest stages, but this direct contractility is soon lost, as well as the indirect. The muscles, whose faradic contractility is only partially lost, may be expected to recover completely, either spontaneously or under treatment. Preservation of galvanic irritability after loss of response to faradism has no very favorable significance, although the loss of galvanic contractions generally indicates a completely hopeless degeneration of the muscle as well as nerve. It is well known that paralyzed muscles which fail to respond to faradic excitation will, unless too degenerate, contract under the stimulus of the interrupted galvanic current. To awaken the contractility of degenerating muscular fibre a certain duration of the stimulating application is required, and this is afforded by interrupted galvanism, while the duration of the faradic shock is too brief. When the muscular degeneration is not too extensive, the induction apparatus with the coarse adjustment-screw will sometimes cause contractions; and the fact shows that the difference in action of the faradic and galvanic current does not depend upon any essential difference in their nature, but only in the difference in the duration of the electric contact with the physiological element to be excited. Although, as declared by the highest authorities, infantile paralysis is the disease which offers the most frequent indications for electro-therapeutics, the theory of its action is still obscure, and the statistics of its practical results doubtful.

Anatomical Lesion of Infantile Paralysis.—The fundamental anatomical fact of infantile paralysis is the acute degeneration of a varying number of neuro-muscular elements,—the ganglionic cell, the nerve-fibre emanating from it, and the muscle-fibre in which this terminates. Since the discovery of the acute atrophy of multipolar cells in the anterior horns of the spinal cord it has been generally assumed that this lesion was the primary one, or at least consecutive to a myelitis, diffused or localized,[1] and that the degeneration of nerve- and muscle- fibre elements only resulted from the destruction of their trophic centre. It has not, however, been proved that the atrophic change always begins in the spinal cell, rather than in any other part of the neuro-muscular unit.[2] It is true that section of a nerve is always followed by degeneration of the segment which is separated from the ganglionic cell. But, on the other hand, those ganglionic centres waste which correspond to limbs that have been amputated. It would seem as if the integrity of the entire nervo-muscular unit were essential to the nutrition of any of its parts.

[1] At one time the atrophy of the ganglionic cells was considered an independent primary lesion. See Petit, Atrophie aigne des cellules motrices, 1873.

[2] Gelineau thinks that the lesion often begins at the periphery and ascends to the spinal cord. Gazette des hôpitaux, 1878. See also *infra*, Starr and Chapin.

It is an important physiological fact, whose influence is noticeable in the pathology of atrophic paralysis, that the nervo-muscular units, each composed of a ganglionic spinal cell, motor nerve, and muscular fibre, are independent of each other, though so closely commingled. Many of these elementary units may be destroyed, while others, immediately adjacent, remain intact. Although the electric current should be quite without effect upon elements profoundly degenerated, it is very possible that it may select others still able to respond,[1] and, by maintaining the nutrition and functions of these, ultimately restore the functions of the limb. Every muscle is supplied with nerve-filaments from several roots, and there are probably many spinal nuclei for each muscle.[2]

In the immense majority of cases the first lesion clinically demonstrable in atrophic paralysis is that of the nerve-fibre, as shown by the diminution, then loss of its reaction to faradic electricity. In autopsies made six or eight weeks after the onset of the disease the motor ganglionic cells are found affected and more or less degenerated. But at this time has also been found extensive hyperæmia, and other signs of a myelitis, not exclusively limited to the anterior horns. Until recently the earliest autopsy was made at six weeks after the first accidents, the child dying of an intercurrent disease.[3] In 1885, however, Drummond described an autopsy where the child succumbed seven hours after the onset of the disease, which attacked the anterior horns of the cord between the third and fourth cervical vertebræ,—thus the origin of the phrenic nerves. The tissue of the anterior horns was intensely vascularized and spotted with minute hæmorrhages; the ganglionic cells swollen; the blood-vessels were distended and choked with blood-corpuscles not only in the anterior horns, but also in the posterior horns and anterior white columns; there was an emigration of leucocytes, while the neuroglia was swollen and profoundly altered.[4]

In the foregoing remarkable case neither nerve- nor muscle- fibre seems to have been examined. Probably no demonstrable lesion would have been found; certainly not if the entire force of the morbific influence were, in this case, concentrated upon the spinal centres, for enough time had not elapsed for the production of a secondary degeneration.

Electric treatment of infantile paralysis is directed either to all the elements of the lesion or to one of them, according to the special preoccupation of the physician in charge. Thus is attempted: To allay the hyperæmia of the spinal cord, which is one element of the initial myelitis, when this really exists (and the paralysis be not due to a peripheral neu-

[1] Shaw suggests that there may be undeveloped cells in the cord which, under proper stimulus, may develop to active ganglionic cells. Kansas City Medical Index, 1888, vol. ix.

[2] Krause-Ferrier, quoted by Simon, British Medical Journal, 1889.

[3] Roger and Damaschino, cited in chapter on "Infantile Paralysis," Pepper's Archives of Medicine.—Putnam Jacobi.

[4] Brain, 1885. "Nature of Spinal Lesion in Anterior Poliomyelitis."

ritis); to maintain the conductivity of the axis-cylinder of nerves, by the passage of electric currents, as a substitute for the nervous currents which have ceased to pass; to maintain the nutrition of muscles, by inducing them to contract under the influence of electric stimulus, replacing that of volition; to contribute to the nutritive regeneration of ganglionic cells, nerve-fibres, and muscle-fibres, by the catalytic influence of the constant galvanic current; to promote the development of other neuro-muscular elements, adjacent to such as have been hopelessly destroyed, but which may possibly be stimulated to assume their functions.

Central Galvanization.—The first method of treating atrophic paralysis is directed toward the hyperæmia, which constitutes one of the initial lesions of the cord, in all cases where poliomyelitis really exists.

Many years ago Legros and Onimus claimed that blood-vessels were contracted by a descending and dilated by an ascending galvanic current.[1] At the present day the direction of the current is considered unimportant; but, since Brenner,[2] the differentiation in property formerly attributed to the direction of the current have been ascribed to the difference in the poles, and referred partly to the phenomena of electrotonus, partly to a special influence exerted on the circulation. In an exposed nerve traversed by a constant current the excitability of the segment at the positive pole is diminished (anelectrotonus), at the negative pole increased (catelectrotonus). This is one of the most fundamental laws of electric physiology. By the prolonged passage of the current a nerve may be completely paralyzed, so that, for awhile, it altogether ceases to respond to faradic stimulation. This experiment has apparently inspired much of the therapeutic belief in galvanism as a "sedative agent" to nervous irritations.

Massey observes that in cathodic closure there is a sudden application of electric energy to the part, at anodic closure a sudden abstraction of the same; "at anodal opening the vacuum produced at anodal closure is suddenly annihilated by the inward rush of the more-normal electric potential of the surrounding tissues," as equilibrium is restored.[3] It is for these reasons that muscular contractions are caused at cathodal closure and anodal opening; correlatively that the excitability of tissues is increased by cathodal closure and lessened by anodal opening.

The experiments upon which such conclusions are based only directly demonstrate oscillations in the electric properties of living tissues. That nerve-force oscillates in a corresponding manner or degree is an inference very possibly legitimate, but still an inference, and not a matter of positive observation. No depression of nerve-force can, however, be desired at any stage of a disease so intrinsically depressing as atrophic paralysis; and during the initial stage of presumed acute myelitis an

[1] Traité de l'électricité, 1865.
[2] Untersuch. auf dem Gebiete der Elektrotherapie, 1868.
[3] Cause of electrotonus, Jour. Ment. and Nerv. Dis., 1886.

exciting action is almost equally undesirable. It is another effect which is aimed at, namely, the alleged "depleting" effect of the positive pole upon the circulation through the contraction of blood-vessels. "Electric currents promote the circulation in blood-vessels and lymphatics. The arrest of circulation at the beginning of inflammation can be dissipated, provided the blood-vessels have not yet become agglutinated."[1] "The anode is depleting, sedative," declares Vigoroux,[2] and it is apparently for such a reason that the high authority of Ziemssen advocates its use in the "creeping inflammations of the nerve-centres."[3]

Sedative Action of Electricity.—This action of the positive pole in contracting blood-vessels has recently received much clinical demonstration through the experiments of Apostoli and his followers with the polar method applied to uterine congestion and hæmorrhage. The positive pole applied to the uterus not only often arrests hæmorrhage at the time, but so narrows the vascular channels that the following menstruation, previously hæmorrhagic, becomes markedly diminished in quantity. Conversely, hæmorrhage is liable to be increased after the application of the negative pole. The establishment of this law gives a new justification to the attempt to diminish hyperæmia, even that of the initial stage of inflammation, by the application of the anode over a focus of inflammation.[4]

In accordance with this theory, now widely if not universally accepted, Erb, in the early stages of poliomyelitis, places a large anode over the presumed focus of the disease.[5] Althaus never uses any other.[6] Seeligmüller, however, from the beginning, places the cathode over the diseased focus, the anode on the spine at the level of the enlargement remaining healthy.[7] It is important that the anode be large, in order to pass to the diseased tissues the maximum amount of electricity, yet avoid all but the minimum amount of sensory irritation. The quantity increases, and the tension diminishes with the size of the electrode, as the impetus of the same volume of liquid is less in a broad channel than in a narrow one. The size of the electrode should be as the square root of the intensity. Thus an electrode of 27 square centimetres and a current of 3 milliampères should only have the same intensity and power of irritation of an electrode of 3 square centimetres and a current of 1 milliampère; yet three times the amount of electricity will have been

[1] Onimus, "Aperçu général de l'action des courants électriques sur la circulation," Bull. gén. de thérap., 1885.

[2] "L'électrothérapie," Progrès Méd., 1891.

[3] Die Elektricität, 1887.

[4] Recently, in a patient of my own affected with menorrhagia dependent on a small uterine fibroid, the negative pole was at first introduced into the uterus, in order to try to secure the destructive influence of the galvanism on the tumor. But the menorrhagia increased. Then three or four galvano-punctures were made with the positive pole, and, for the first time in three months, the succeeding menstruation was normal.

[5] Handbuch der Elektrotherapie, 1886.

[6] Infantile Paralysis.

[7] Gerhardt's Handbuch der Kinderkrankheiten, 1880.

passed into the body.[1] Most authorities pass the current only from two to five minutes. Bouchut uses a very weak current for several hours.

Nutritive Action of Electricity.—After the subsidence of the initial hyperæmia, and when blood-vessels and nerve-elements simultaneously begin to atrophy, according to these same theoretical considerations, the spinal cathode is required. It is essential, if possible, to try to arrest the processes of retrograde metamorphosis which have begun in the anterior horns of the cord; and the most exciting influence of electricity is invoked, because it is claimed that "every organ submitted to the action of electricity reacts characteristically, and always in the sense of a regeneration of the diseased parts."[2]

"The cathode is exciting, causes hyperæmia by dilatation of arterioles, increases nerve excitability."[3] "Electricity is unquestionably a stimulant to processes of nutrition. It is a tonic to healthy tissue, and favors the restoration of healthy nutrition in tissues whose vitality has become impaired."[4]

Such hypotheses are the modern expression of the "catalytic" theory of Remak. "The nature of this action is entirely obscure. . . . It is probably due to some influence exercised upon trophic and vaso-motor and secretory nerve-fibres . . . affecting the rapidity and direction of the plasma-stream, perhaps also the functional activity of nerve-cells."[5] Seeligmüller[6] says that "electricity, as the antiparalyticum *par excellence*, deserves the utmost confidence in spinal paralysis, and especially the constant current applied centrally." Soltmann[7] also calls electricity "the most powerful excitant of nervous power." Its employment is difficult, but indispensable. Gelineau[8] says that electricity is the touch-stone of the disease. He quotes a case related by Bouchut, where, in a paralyzed deltoid, but a single fibre (!) had been spared. Faradic stimulation, "acting upon this point as a centre," gradually restored the contractility of a good part of the muscle, and the patient recovered complete liberty of movement. Morton Prince[9] observes, "The results of electricity in infantile paralysis, even of long standing, have been, in my experience, so positive that I think this method should be used by every one. Many spinal centres (*i.e.*, ganglionic cells) recover which had been only indirectly affected by inflammation, through œdema and pressure. Nevertheless, the muscular fibres connected with these cells may still remain paralyzed, unless treated by

[1] Mund, "Dosage of Constant Current," Berlin. klin. Wochenschrift, 1892.
[2] Pierson-Sperling: Lehrbuch der Elektrotherapie. Leipzig, 1890.
[3] Vigoroux, *loc. cit.*
[4] De Watteville, *loc. cit.*
[5] *Loc. cit.*, p. 375.
[6] *Loc. cit.*
[7] Gerhardt's Handbuch der Kinderkrankheiten, 1880.
[8] Gaz. des hôp., 1878, p. 841.
[9] Boston Medical and Surgical Journal, 1890.

electricity." The author claims to have "repeatedly" seen children, who could walk or use their arms only with great difficulty, immediately begin to recover power after electric treatment." Murrell, basing his opinion on notes of fifty-six cases observed during six years, believes "that the majority of cases, when seen early, may be cured."[1] This physician does not rely exclusively upon electric treatment. During the first days he gives aconite or bromide if the child have convulsions. When the child begins to go about, blisters are applied to the spine and physostigma given in doses of $\frac{1}{60}$ grain. In six weeks later he adds to the latter $\frac{1}{200}$ grain phosphorus. When the acute stage is over he submits the limb to massage under a competent person, and at once induces the muscles to contract under electricity. This can sometimes be done after massage, when it was impossible before. Interrupted galvanism must be used to the muscles at first; later, when they will contract to faradism, the constant current should be employed. From the beginning galvanism to the cord does good.

From the time, therefore, that the acute symptoms of the attack have thoroughly subsided, and faradic excitability been lost, the exciting action of electricity is required over the entire neuro-muscular apparatus, whose elements have begun to atrophy. Hence the cathode should be placed, first over the spinal column, at the central focus of disease, then systematically all along the limb. By this means we may hope to aid the regeneration of the atrophied neuro-muscular elements, and to avert the degeneration of others which may have been less severely injured.[2]

Now that we know that each nerve-fibre is connected with a single ganglionic nerve-cell, and, conversely, that each cell sends out only a single fibre; further, that every muscle is supplied from several nerve-roots; finally, that the lesion in poliomyelitis affects an undefined number of isolated motor elements,—cell, nerve-fibre, muscle-fibre,—these commingled, but yet preserving their physiological and pathological independence,—it is conceivable that we might be able to stimulate the nutrition of some elements yet responsive to the electric current, even though others, closely adjacent, remained unaffected, permanently lost. For this purpose, however, is certainly to be preferred the systematic application of the negative pole over each segment of the limb in succession, beginning at the spinal cord, where the paralyzed nerves originate.

Electrical Muscular Contractions.—The third method is an indirect mode of stimulating the nutrition of the paralyzed muscles. Incapable of voluntary contraction, muscles lose the normal stimulus to nutrition. Muscular contractions artificially induced will, to a certain extent, imitate

[1] Clinical lecture on treatment of infantile paralysis. London Lancet, ii, 1885.

[2] Lewis (Arch. Pediat., vol. iii, 1886) directs to "exercise the muscles with electricity, passing a galvanic current with positive pole placed over muscles" This direction is only intelligible if such degenerated muscles are meant as only contract to the anode closure.

the normal stimulus and avert muscular atrophy.[1] It is difficult to prove a nutritive value in the contractions induced by faradic electricity, for the reason that any muscle which contracts, even feebly, under its influence, will often, after a time, recover spontaneously. But when faradic contractility has been lost, the interrupted galvanic current may act directly upon the muscular fibre, which, isolated from its nerve, does not respond to the too-brief shock of the induced current. This direct excitation is of value only to the extent to which the muscular contraction itself, apart from nervous influence, is really efficacious in quickening the circulation and the nutritive processes within the muscular tissue.

Helmholtz[2] has shown that every muscular contraction, though artificially excited, is accompanied by a rise of temperature proportioned to the energy and duration of the contraction. The thigh-muscle of a frog, measured with a thermo-electric apparatus, after a tetanus of two to three minutes, showed an increase of temperature of 0.14° to 0.18° C. In this case the nervous system was intact, and the muscle contracted through the intermediary of the stimulated nerve. But Ziemssen found, after the passage of a constant current which caused no contraction, that the temperature did not rise. The same rise of temperature has been observed in the muscles of living human beings. Other phenomena accompanying the muscular contraction are the consumption of stored oxygen and the increased formation of products of retrograde metamorphosis,—all pointing to an increased nutritive metabolism. The increased movement of disassimilation which results in the formation of explosive compounds—hence the potential production of motor force—contributes indirectly to tissue nutrition, through the more intense movement of assimilation by which it is succeeded. Another part of the self-regulating nutritive mechanism of muscles consists in the special disposition of their blood-vessels, which Ranvier has described.[3] The capillaries form quadrangles over the fibre, and each contraction of the latter so compresses the vascular net-work as to quicken the circulation of blood through them.

According to the theory of du Bois-Reymond, which admits the existence of a natural electric current in muscles, passing between their surface and their extremities, the equalization of chemical reactions during muscular contraction is a circumstance which favors nutrition. When a muscle is in repose, the reaction on its surface is neutral or acid; at the interior, alkaline. During muscular contraction the conditions gradually become equalized, and the entire muscle is in the same state of oxidation. The electric current gradually diminishes in force,

[1] The depressed nutrition of the paralyzed limbs, which affects the growth of the bones, sometimes so impairs their nutrition as to leave them liable to spontaneous fracture. See a rare case by Berbez, France Médicale, 1887.

[2] Quoted by Ziemssen. *loc. cit.*, p. 80.

[3] Traité d'Histologie.

and finally assumes the inverse direction.[1] This oscillation is supposed to favor the streaming of plasmodic currents through the tissue.

D'Arsonval draws some further deductions from the electrical laws of fluids situated as are the fluids and protoplasm in muscular fibre. According to Ranvier, again (his description of muscular blood-vessels has already been quoted), the muscle-disks form little independent organisms, separated from each other by layers of fluid. Each fibre, therefore, consists of superposed alternating strata, the disks of protoplasm (disks of Bowman), and narrow layers of fluid between them. The opposing surfaces of the disks are in a state of electric tension at the point of separation, and the degree of tension is an exponent of their difference in potential. For, "the superficial electrical tension at the point of separation of two liquids is an exponent of their difference in potential, and living tissues follow the same law." When the point of separation is altered, by increasing the distance between the disks, a variation in potential is produced; hence an electric discharge in a direction opposed to that of the movement. This is the law for opposing fluid surfaces, and it must be the same for organic tissues. Therefore, the contraction of a muscular fibre, by changing the electrical tension on the surface of the disks, is accompanied by an electric discharge, which expresses itself in the negative variation of the galvanometer needle, placed in appropriate connection with the muscle. The variation is negative, because the movement of the muscle-current is in the opposite direction to the wave of motion in the fibre. When the muscle is elongated by traction, a positive variation of the galvanometer needle is observed. As the current developed within the muscle always runs in an opposite direction to the current thrown into the muscle, the negative pole is more stimulating than the positive, for at the negative pole the muscle-current is positive. The muscle is an electric motor rather than a thermic motor. Heat is the *result* of the contraction, not the cause of it. The movement of particles in the protoplasm and fluids of the muscle follows the electric discharge, and hence the latter constitutes the most energetic excitant of nutrition.[2]

Thus, apart from nervous influence, muscles possess, in their intrinsic activity, the means of regulating their own nutrition. The nervous influence, indeed, seems to mainly act as the means of exciting muscular contractility, and may, therefore, be replaced by agents capable of doing the same thing. It is thus possible, by means of the interrupted galvanic

[1] Onimus, "Currants electriques naturels. Leurôle dans la nutrition," Gaz. méd. de Paris, 1886. It is well known that the physiologist, Hermann, has always denied the existence of an electric current in living muscle, and claimed that the current observed is developed in the dying muscle, between the intact natural surface and the surface of section.

[2] "Relation entre l'electricité animale et la tension superficielle," Comptes Rendus Acad. Sciences, 1888. D'Arsonval describes an ingenious schema of the muscular fibre: A rubber tube, divided by porous disks into compartments, each containing a layer of mercury covered by a layer of acidulated water. Each end of the tube was connected with a rheoscope, and a weight was attached to one end. As the tube was alternately lengthened and shortened, the galvanometer was traversed by alternating currents.

application, to preserve the nutrition of muscles, even though the paralysis remain unimproved. On the other hand, the muscular contraction itself probably stimulates the nervous fibrillæ running into the muscular end-plate, and thus acts as a means of arousing nervous activity. Meltzer has ingeniously applied this view to the interpretation of contraction in the cardiac muscle. (See *Medical Record*, May, 1893.) Anger relates the case of a baby, 15 months old, with paralysis of the anterior tibial of one leg. Electricity was applied daily to the muscle, and at the end of three months the paralyzed limb was larger than its fellow. But so soon as treatment was interrupted the advantage gained was lost, and paralysis became more marked.[1] Of similar significance are the experiments of Professor Thacher, in a case of bilateral paralysis of all the extremities, due to diphtheritic multiple neuritis. Each arm was treated alone for a week, by a labile constant current applied daily for ten minutes. As measured by the dynamometer, this muscle was found to have gained in strength to a degree far greater than that of the untreated arm. Thus, after ten days' treatment to the left arm, there was a gain of 17 degrees, while the untreated arm had only gained 12 degrees. After seven days' treatment to the right arm, this in turn gained 15 degrees, while the left arm, untreated, gained only 10 degrees. Under faradism there was no gain perceptible, and under massage there was a positive loss.[2]

Wood only recommends electricity as a means of preserving the nutrition of muscles, since "the injured spinal cells can never be restored."[3] Rockwitz also recommends the constant stream, in order to improve the nutrition in atrophied muscles;[4] so Eardley.[5] And, notwithstanding all the considerations that indicate the nutritive value of muscular contractions, Massey claims that, in the treatment of infantile paralysis, "faradism is unscientific and totally useless. Galvanism only should be used. Even though it fail to cause contraction, its catalytic effect is beneficial.[6]

Centripetal Stimulation (*Fourth Method*).—By a fourth form of electric treatment the nerve-centres are stimulated not by the passage of a galvanic current directly applied over the spine, but through electric stimulation of the afferent nerves on the surface of the body, and the irradiation thence, along normal channels, of the stimulus to the spinal centres at which these nerves abut. For this purpose faradization, and especially as applied with a dry electrode or even the electric brush, is preferable to galvanism.

Faradization.—It is well known that Duchenne never ceased to uphold faradization as *the* remedy for infantile paralysis, although it does

[1] Hammond (Treatise on Nervous Diseases) was one of the first to insist on the value of direct excitation of the muscles by galvanism when faradic contractility was lost.

[2] Medical News, 1885.

[3] New York Medical Journal, 1883.

[4] Deutsch Zeitschr. f. Chir., vol. xix, 1883.

[5] "Action of Electricity in Disease," Australasian Medical Journal, Melbourne, 1891.

[6] "Early Management of Infantile Paralysis," Philadelphia Medical Times, 1883.

not possess direct nutritive properties nor chemical action, and in all severe cases of the disease fails to manifest its characteristic property of exciting muscular contraction. Yet even then it still continues to excite pain; that is, to irritate sensory or afferent nerves. This irritation, transmitted to the ganglionic centres in which the nerves terminate, may act as a stimulus to quicken molecular processes in their protoplasm, although the electric current itself fail to reach the nervous tissue.[1] Stimulation of a ganglionic centre irradiates, or is transmitted to, or in some manner affects, the nerve-fibres emanating from this centre. Therefore, although again the electric current itself is not reflected, there may be said to be a reflex stimulation of the nutrition—at all events, of the metabolism—in the nervo-muscular elements on the periphery. But it is to be remembered that an irritation of nerve-tissue, though a stimulus, does not necessarily stimulate nutrition. Indeed, the distinguishing characteristic of the faradic current is, that it elicits a functional activity; and this is only indirectly, and under entirely favorable circumstances, a stimulant of nutrition. A ganglionic cell that wastes is a cell in which processes of disassimilation are constantly preponderating over processes of assimilation. The ultimate therapeutic problem is the reversal of this preponderance. Since all functional activity implies and depends on processes of disassimilation, it would seem at first as if such activity should be sedulously avoided, and only rest sought. There are many indications that this supposition is true, whenever nervo-muscular wasting is due to a primary movement of denutrition. Thus, in progressive muscular atrophy, artificially-induced muscular contractions aggravate the disease. The benefit sometimes accruing from faradization to muscles wasting in infantile paralysis itself tends to indicate that the muscular atrophy, though so precarious, is, in such cases, due largely to inaction, and therefore may be moderated by the degree of activity possible under artificial stimulus. Nevertheless, there must be theoretically inferred a marked superiority of the galvanic over the induced current, in the treatment of any one of the three lesions in atrophic paralysis,—whenever, that is, that an electric current is to be applied directly to the diseased elements. For the galvanic current excites a movement of liquids in the plasma of tissues favorable to nutrition, yet, while constant, arouses no function in either muscle or nerve. There is thus no danger of fatiguing either from premature activity. The reason that the faradic current may, however, also be beneficial, is that it does not reach the wasted ganglionic cells; nor, if limited to the skin by a dry brush, does it penetrate to the paralyzed muscle or motor nerve. But the stimulating irritation it causes in sensory nerves is conveyed to the posterior roots and horns of the cord, and only after dissemination among the cells and network of this region can it, secondarily and mediately, affect the motor

[1] Faradic electricity, as first announced by Duchenne, does not penetrate far into the tissues,—certainly does not reach the spinal cord; it is a current of tension, not of quantity.

cells. It is conceivable that a stimulus so subdivided and transformed should affect the molecular processes in these cells in quite another manner than if it were directly applied to them, and that this mediate stimulus should be really beneficial.

Static Electricity.—A form of electricity still higher in tension and lower in quantity than the faradic current is the static or franklinic electricity. This, after having almost fallen into oblivion, has recently been resuscitated as an agent of great value,—not for any local effects it produces, but as a powerful stimulant—by sensory irradiation—of the nerve-centres. The pronounced localization of atrophic paralysis has long made it appear a disease unsuited to treatment by a method which acts, when at all, by the widest diffusion. There is, however, at present a greater tendency to regard the nervous system as a unit whose localized lesions must be treated not only locally, but by methods which may modify the nutrition of the whole. "The general effect of electrization is increased activity of nutrition, calorification, respiration, and a subjective sensation of *bien étre.*"[1] These effects, which Beard and Rockwell for many years claimed for their methods of general faradization and central galvanization,[2] Vigoroux declares are at their maximum after franklinization. Few cases of poliomyelitis seem as yet to have been treated by this method. One is reported by Shaw,[3] where no muscular contractions could be obtained in paralyzed muscles by faradism; the galvanic current gave contractions only with the anodal closure (A. C. C.), thus reaction of degeneration, but static electricity procured at once fairly good muscular contractions. It was applied to various points about the leg ten minutes daily. The galvanic current was also applied, and massage used. After two months the child was greatly improved.

Thus, though hysteria, neurasthenia, anæmia, and rheumatism have seemed to be the diseases to which static electricity was especially applicable, yet the highly-localized affections of atrophic paralysis may also, in the future, be treated, at least in part, by this powerful agent.[4] In part only, for the indications already described for central, peripheral, and reflex electric currents—galvanic and faradic—must continue to demand their aid, no matter what degree of benefit can be derived from the diffused franklinization.

If, from theoretical considerations, we pass to the practical inquiry, "How often, in fact, does electric treatment cure infantile paralysis; and, when it fails, what is the reason?" we obtain very varying, and often very unsatisfactory, replies. As a rule, electric specialists are ready to affirm uniformly good results from electric treatment, if applied sufficiently early.[5] Seeligmüller, whose monograph on poliomyelitis is

[1] Vigoroux, Progrès Méd., 1891.
[2] Treatise on Electricity, 4th ed., 1888.
[3] Kansas City Medical Index, 1888.
[4] Eulenberg says: "Static electricity has a narrow but positive field of usefulness."
[5] Vigoroux, though so much identified with electro-therapeutics, and especially with static electricity, nevertheless ridicules the idea of an electrical specialty. "Je le veux bien, il s'agit d'electricité, mais si peu! Pas plus en tout cas qu'il ne s'agit de mécanique en chirurgie, d'acoustique en auscultation et en otologie, d'optique en ophthalmologie." *Loc. cit.*

most comprehensive, having pronounced electricity the "antiparalyticum *par excellence*," nevertheless admits that "success with it is only obtainable in recent cases." In 1879 [1] Simon advised the application of electricity in two to four days after occurrence of the paralysis, and declares that the prognosis is fairly good if the paralysis advances *slowly* during the first three weeks. In 1889 an English writer of the same name observes "that although galvanism and faradism have had some success, it is, unfortunately, in so small a number of cases as to furnish no precedent for favorable prognosis." [2]

Gray expresses the conviction of many when he says that it is impossible to find any means which shall resurrect a dead ganglion cell.[3] Deahofe thinks it "doubtful whether any remedies, including galvanism to the spine, have any influence [4] over the recovery of nerve-elements. Yet this writer advises the use of the interrupted galvanic current to maintain the nutrition of the muscles until, by spontaneous recovery (of neuro-muscular elements shocked for a time out of functional activity, but remaining structurally intact), the faradic contractility be restored. Though Althaus advises galvanism, he hopes little from it. Hughes Bennett studies the electric reactions of "atrophic paralysis," —himself having devised this name,—but has very little hopes from electric treatment.[5] Eisenlohr, emphasizing the diffuse myelitis of the gray substance found in many cases of infantile paralysis, observes that galvanism is of little service.[6] Forster relates, together with cases of cerebral paralysis, several cases, evidently spinal, which remained quite unimproved by the galvanic current,—applied, it is true, several years after the onset of the disease. In the first the duration had been six and one-fourth years, the second five to six years, the third only five weeks; but the atrophy was already considerable.

"Electricity," says Gowers, "has been strongly advocated and largely used in the treatment of infantile paralysis, and there is reason to believe that it is useful, although its influence has been much exaggerated. In no sense is it a curative agent, and there is no evidence that its application to the spine is capable of increasing the degree or accelerating the course of the recovery of the nerve-elements. Nor is it easy to obtain evidence of its influence over the muscles. If the wasting is rapid, this progresses daily, in spite of daily and sedulous applications. Nevertheless, its demonstrable effect on the muscles, in causing their contraction, must have an influence in the right direction upon their nutrition. This is of no avail if no recovery takes place in the spinal cord, but in most cases some recovery in the cord does occur." [7]

Starr declares that he has never seen a case of organic disease of

[1] Gaz. méd. de Paris, 1879.
[2] British Medical Journal, 1889.
[3] International Clinics, April, 1891, p. 212.
[4] "Poliomyelitis," Arch. Pediat., 1889, p. 592.
[5] Brain, vol. vi.
[6] Deutches Arch. für klin. Med., Bd. xxvi, H. 5.
[7] Diseases of the Nervous System, p. 270.

the brain or spinal cord cured by the application of electricity. In diseases of the brain he considers electric treatment useless. In infantile paralysis he is not convinced that recovery is at all aided by electricity.[1] Lee[2] has watched cases under electric treatment for three to six months, and compared them with similar cases untreated, and found no difference. He thinks powerful currents injure the nervous system of children.

It is equally difficult to obtain statistics from the advocates and from the skeptics of electric treatment. Prolonged research among medical reports only serves to discover illustrative cases. Thus, Beard and Rockwell, in the fourth edition of their treatise, in 1888 cite the following four cases:—

1. Child 14 months old. After exposure to cold, complete paralysis of the left arm. This occurred a week before treatment. There was atrophy of the deltoid with a loss of faradic contractility, but reaction to galvanism. After galvanic applications faradic contractility returned. Recovery in a month.

2. Paralysis of left arm and atrophy of deltoid a few days before consultation. Faradic contractility lost, galvanic retained. Almost perfect return of voluntary power after twenty applications, but faradic contractility remained feeble.

3. Girl aged 14. Paralysis of right leg after diarrhœa. Treatment begun in six weeks. Unusually rapid improvement. Perfect cure.

4. Boy aged 4. Paralysis of right leg since six months. Atrophy; loss of faradic contractility. This was partly restored after six months' treatment. After a year the child was able to walk with a chair.

In 1853 Gull reported quite a series of cases of "spinal paralysis" successfully treated by electricity:—

1. Boy aged 12 months. Feverish for a week, with diarrhœa. Then a restless night, and on the next day the right arm was paralyzed, especially the deltoid. Treatment begun six weeks later, when muscles were wasted; boy only able to move the fingers. Treated by static electricity, much improvement was apparent in three months; can raise his hand to the mouth. Fortnight later, can move his arm and hand in any direction, though still slight feebleness.

2. Child of 20 months. Sudden paralysis of left leg at six months. Static electricity was used. Much improvement in three weeks. In five weeks could run about.

3. Child of 21 months. Both arms found paralyzed one morning. Static electricity a week later. In three weeks can raise right arm to head.

4. Boy of 10 months. Paresis and flabbiness of left leg. Static electricity; recovery

5. Boy of 13 months. Lost power of right leg during recovery from gastric fever. Under static electricity gradually regains power of motion.[3]

A very carefully observed case is related by Friedländer[4]:—

Girl aged 11. Sudden illness; acute gastric catarrh and fever; transitory pains in cervical spine, then paresis,—first in left, then in right arm. After one day found in right arm limitation of movements of shoulder forward and outward, and weakened flexion. The left arm was completely paralyzed, except for some slight movements of fingers. Heaviness in legs; sensitiveness over fifth, sixth, and seventh cervical and first dorsal vertebræ. Loss of tendon reflexes at arms. No disturbance of sensation. Electric treatment begun at

[1] "Electricity as a Therapeutic Agent," Medical News, 1889.
[2] Medical Press and Circular, 1884.
[3] Guy's Hospital Reports, 1853.
[4] Centralblatt f. Nervenheilkunde, 1887.

once. An anodic electrode of fifty-five square centimetres was placed at three successive stations over cervical spine, the cathode, of the same size, placed at first on sternum, later on epigastrium. A current of 2, 2½, and 3 milliampères was passed forty-five seconds for each station, thus two minutes in all. The application was made daily. Improvement at once. In two days temperature normal; lassitude vanished; appetite excellent; yet affection showed tendency to progress toward the lower extremities. But after three weeks' treatment the movements of the right arm were entirely normal except at deltoid, where, later, faradic contractility returned. After twelve weeks the left arm also was restored, though rather weak.[1]

Warner[2] analyzes 18 cases of infantile paralysis: 7 were in the arm alone, of which 5 recovered; 9 in the leg alone, of which 1 recovered; 2 hemiplegic, 1 recovered completely; 1 recovered entirely in the arm, partially in the leg. Edge,[3] in the same journal, relates the case of a boy of 10, paralyzed in both lower extremities, in the muscles of the back, and the extensors of forearms. Faradic contractility diminished, cutaneous sensibility impaired. Case rapidly improved to complete recovery. Graeme Hammond[4] relates three cases of successful treatment of poliomyelitis. Steavenson treated eleven cases of infantile paralysis by electricity; six improved, five did not. One case, with almost complete paraplegia, was greatly improved by the electric bath.[5]

The data do not at present exist whereby we may arrive at any definite conclusions in regard to the electro-therapeutics of infantile paralysis. It may be permitted, however, to hazard the following suggestions: In the first place, it is very possible, even probable, that the so-called infantile paralysis is not always the same disease, or, rather, that the neuro-muscular lesion we perceive, though the same in appearance, yet results from different pathological injuries. Thus, diphtheritic membrane may be caused by a poison which is now relatively mild, now possessed of the most deadly toxic properties. Hence, all indications are not met by beginning the treatment early, because in some cases the injury may have at once smitten the vitality of the neuro-muscular elements so profoundly that recovery is impossible. Or, again, the injury may have been so widely distributed that no elements remain intact in the given area. Nevertheless, it is undoubtedly important to begin treatment as soon as possible. During the first week, while fever often persists, and while faradic contractility is constantly diminishing, the nerve-elements are still in a state of shock. Absolute rest is the first requisite, and any attempt to excite muscular contractions liable to be disastrous. The child should be put to bed, kept as quiet as

[1] Howard (Lancet, May 31, 1884) relates a case of recovery without electric treatment, in a girl of 12, who was affected with paralysis of the right arm and leg at 2 years of age. Gradual improvement, but still paresis and atrophy, with diminished faradic contractility. Treated successfully by warmth, friction, warm douche, passive exercise. After some months patient could walk with scarcely perceptible limp.

[2] British Medical Journal, 1880, vol. ii.

[3] *Ibid.*, p. 169.

[4] Journal of Mental and Nervous Diseases, January, 1893.

[5] St. Bartholomew's Hospital Reports, 1883.

possible, and on an easily-digestible diet, so as to avoid all gastro-intestinal complications. At this time electric treatment may be begun, by placing a large anode over the spine, at the presumed focus of the myelitis, or in succession at different points if needed. The cathode having been placed on the sternum or abdomen, a weak current of not more than 5 milliampères should be passed for two or three minutes. This daily or, possibly, twice a day.

When the faradic contractility remains stationary the acuteness of the destructive process may be supposed to have subsided, and the indication now presents itself to try to stimulate the assimilative processes of nutrition. For this purpose the cathode should be placed, first over the spine, then in successive stations along the limb. The *séance*, at first occupying five minutes, may gradually be extended to ten. A daily *séance* is usually advised, but this may be rather in accordance with the convenience of the physician than for the real advantage of the patient. It is quite possible that a brief application morning and evening would be followed by better results. After a month, in addition to the foregoing treatment, the paralyzed muscles should be daily stimulated to contract by means of the faradic or the interrupted galvanic current. Surface faradization, and also static electricity for general central stimulation, should also be used. The electric treatment should be aided by systematic massage and hot and cold douching, into which auxiliary treatment it is not now our province to enter.

The most cursory observation shows that few cases of infantile paralysis ever receive such carefully-methodized treatment as has been detailed above; still less is treatment begun promptly or continued with persistence. In hospital and dispensary practice, children are indeed brought to the physician by alarmed mothers the moment the paralysis appears; but after a few electrical applications the women become discouraged, the children increasingly rebellious, and the case is left to see what "nature will do." In private practice the expense of the prolonged treatment necessary is often a serious obstacle to its efficient prolongation. It would then be better—where the mother is reasonably intelligent and attentive, and has watched, with a view of learning, the physician make the first applications—to advise her to purchase an electric apparatus, and herself carry out the precise directions of the physician. The chloride-of-silver batteries (faradic and galvanic) are excellently adapted for home use. Treatment with static electricity, owing to the complication of the machine and its great expense, would always need to be given at the physician's office; but two *séances* a week would suffice for this part of the treatment.

Only the statistics of the future, and based upon early, methodical, and prolonged treatment, will be of use in estimating the therapeutic resources at our disposition for the treatment of infantile paralysis, before we should be compelled to hand the little patients over to the

orthopædists for mechanical palliation of any incurable deformities. A period of two years is not too long a time to assign in advance. The cases brought for treatment after months and even years of paralysis, atrophy, and muscular retraction[1] should no more be counted in the statistics of electro-therapeutics than ankylosed dislocations in the statistics of rational surgery. In the meantime it is most desirable that every case submitted to treatment should be placed on record.

Poliomyelitis will always offer a fascinating field for therapeutic experimentation, for it involves the most central problems of nutrition of nervous tissues and elements. This wasting ganglion cell, this attenuated nerve-fibre, and this atrophied muscle held locked within the mysterious streamings of their protoplasm the hidden secrets of all bodily life. In frequency and pathological importance poliomyelitis is in pediatrics what locomotor ataxy is in adult life. But, whereas in the latter disease the essential lesion is a systematic sclerosis, in poliomyelitis it is, in the most serious forms at least, an atrophy of ganglionic cells and of their prolongations.[2] The second contrasting fact is perhaps linked with the first, namely, that electric treatment is far more often successful with poliomyelitis than with locomotor ataxy,—indeed, it is doubtful if an electric cure is ever obtained for the latter disease. A remedy which has often relieved, at least symptomatically, locomotor ataxy has registered one success with poliomyelitis,—I mean nerve-stretching.[3] It is possible that the hypodermatic injections of nerve-tissue extracts—for which Brown-Séquard and his followers are claiming success in the treatment of so intractable a disease as locomotor ataxy—may some day also be used to raise the nutrition of nerve-elements in spinal atrophic paralysis.

[1] Such cases lead orthopædists to declare positively, "It is a waste of time to try to restore wasted muscles or nerve-cells by electricity." Gibney, "Limitation of Therapeutics in Infantile Paralysis," N. Y. Med. Record, 1886.

[2] Pasteur relates a case of infantile paralysis limited to the bulbar nuclei, and leaving paralysis of the face and tongue. Lancet, 1887, ii, 858.

[3] Simon, whose unfavorable opinion of electricity has already been quoted, relates the following case where the nerve was stretched. The patient was 5 years old, had been under treatment during three years for paralysis of the right leg, and for two years electricity had been continually applied. This seems to show that electric treatment was only begun a year after the occurrence of the paralysis, which is much too late. The author thinks that the electricity had averted deformity and maintained a fair degree of nutrition in the paralyzed muscles, but the paralysis was unimproved. The muscles supplied by the sciatic nerve contracted under galvanism. No faradic test is mentioned. The sciatic nerve was exposed, raised, and stretched. In two months the limb had gained one-fourth inch in circumference, and the power of walking was very much improved.

Howard, in a lecture on infantile paralysis, describes no treatment but heat and massage (Lancet, 1884, i, 973). Taylor only refers to the electric current as a means of diagnosis (Tr. Clin. Soc., London, 1882, xvi). The little epidemic of infantile paralysis described by Medin at Stockholm indicates some general infection in the cases there observed. Forty-four cases occurred between May and November, of which 29 were in August and September, and 4 were fatal. Autopsies in the latter discovered not only parenchymatous inflammation of the anterior horns, but dark, fluid-blood ecchymoses under the pleura and endocardium; cloudy swelling of the elements of the heart-muscle, spleen, liver, kidney; of the solitary follicles, Peyer's patches, and mesenteric glands of the intestine, and hyperæmia of the brain. Thus the disease seemed analogous to cerebro-spinal fever, with, however, peculiarly limited spinal lesions. The cases, however interesting, throw little light on the ordinary sporadic disease. (Internat. Med. Congress, 1890.)

Compression Myelitis.—A form of myelitis which is about as frequent among children as atrophic paralysis is the compression myelitis due to Pott's disease.[1] When, as sometimes happens, this occurs precociously, while the angular curvature is still insignificant, it may, with a superficial examination, be mistaken for poliomyelitis. The diagnosis, however, is not too difficult; and it is appropriate to note that in making the diagnosis electricity offers an important aid. Faradic contractility, like the reflexes, is preserved in compression myelitis, lost in poliomyelitis. This diagnostic value is the greatest which electricity offers in this disease; for when compression of the cord is removed, spontaneously or by means of sustaining apparatus, the paralysis will subside; and, conversely, until this has been accomplished, no form of treatment will be of much avail. *Local* faradization is sometimes used in order to preserve the nutrition of the muscles until the paralysis shall have been relieved. But as in typical cases there is no degeneration of ganglion cells, but a sclerosis of white columns, annular at the seat of the spinal lesion, occupying the lateral columns, if descending degeneration by misfortune occur, the danger to muscular nutrition is comparatively slight. Nevertheless,—and if it can be done without causing central irritation by irradiation,—local faradization may sometimes be advised.

Paralysis of the Diaphragm.—One form of paralysis due to compression myelitis may occasionally occur, and demand faradization as a matter of urgency,—I mean paralysis of the diaphragm. The indications for and mode of treatment are then the same as in diphtheritic paralysis of the diaphragm.

Diphtheritic Paralysis.—The exact seat of the lesion in diphtheritic paralysis is not decided, or, rather, it is not always the same. In the majority of cases so far investigated it seems to depend on a form of multiple neuritis, which is sometimes general, sometimes especially affects the peripheral terminations of motor nerves, sometimes their anterior roots.[2]

Déjerine describes the autopsies of three cases, in all of which the four extremities were paralyzed. In the nerve-fibres of the anterior roots the axis-cylinder had disappeared; the myeline was dissolved; there was an abundant proliferation of nuclei in the nerve-sheaths. Starr[3] quotes from Kast the following case:—

A girl of 13, after suffering a few days from a slight sore throat, became affected with paresis of ocular accommodation, then progressive ataxia, first of the upper and then the lower limbs; disturbance of touch, pain, temperature, and muscular senses, with delayed sensation of pain and loss of tendon reflexes. Then bulbar symptoms set in, accompanied by muscular atrophy in the hands, where faradic reaction was lost. Death from pneumonia in nine months. The autopsy found well-marked atrophic degeneration in all the nerves of the extremities, as well as in the hypoglossal and recurrent laryngeal.[4]

[1] Vulpian calls the pathological tripod of Pott's disease spinal deformity, abscess, paralysis.

[2] Buhl.

[3] "Multiple Neuritis." Middleton Goldsmith lectures, 1887.

[4] Deutsches Arch. für klin. Med., 1886.

Starr quotes a similar case from Mayer[1] and another from Mundel.[2] Although diphtheritic paralysis be most frequently due to a peripheral neuritis, the disease sometimes attacks the anterior horns of the cord. The case, then, does not differ, except in etiology, from ordinary cases of poliomyelitis.[3] The usually favorable termination of diphtheritic paralysis, as contrasted with the usually serious prognosis in atrophic paralysis, would alone suffice to indicate that the cord is only exceptionally affected in the former disease.

The tendency of diphtheritic paralysis to spontaneous recovery makes it difficult to estimate the real value of electric treatment. The experiment of Professor Thacher's has been already quoted, where, in a diphtheritic paralysis of four limbs, faradic electricity was applied to each alternately for a certain number of days, and the gain in muscular strength during this period, compared with that of a period without treatment. Starr, usually quite skeptical in regard to therapeutic values of electricity, cites this experiment as proving a positive nutritive influence of electrical treatment.[4]

Baginsky employs a weak faradic current to the muscles in all cases of diphtheritic paralysis, but associates with it the administration of strychnine, and the latter custom is general.[5] Diphtheritic paralysis is only dangerous when attacking the cardiac muscle or the muscles of respiration, and for these dangers strychnine is a more powerful remedy than electricity, provided it have time to act; while for heart-failure electricity cannot be used at all. Toxic paralyses are all peculiar in the circumstance that they begin under the influence of a poison then circulating in the blood. Whether recovery begins with the moment of elimination of this poison is not known; it certainly, however, will not begin before. Electric treatment should be conducted according to the rules for treating peripheral neuritis. Weak galvanic currents should be passed through the nerves of the paralyzed limb or limbs,[6] but faradic contractions, though often attainable, should be avoided. Static electricity may also be used as a general nerve-tonic. The poison sometimes, though rarely, attacks the respiratory ganglia of the medulla in such a way as to simulate—say, rather, to cause—an acute bulbar paralysis.[7] This bulbar form may be mistaken for a capillary bronchitis. But in the respiratory system, as elsewhere, the habitual localization of the diphtheritic poison is peripheric; it is the diaphragm or the intercostal muscles which fail. In this case, intermittent faradization of the phrenic nerve may serve to antagonize the action of the diphtheritic poison just

[1] Virchow's Archiv, 1888.

[2] Neurol. Centralblatt, 1885.

[3] Kidd insisted that the anterior ganglion cells of the cord were always attacked in diphtheritic paralysis. This opinion was justly opposed by Buzzard and Parker. Lancet, 1883.

[4] Medical News, 1889.

[5] Archiv f. Kinderheilkunde, 1891.

[6] Archambault, Gaz. des hôpitaux, 1882; so, also, A. Jacobi, Archives of Pediatrics, 1889.

[7] Guthrie, Lancet, April, 1891.

as it has proved able to antagonize the benumbing influence of narcotics or of carbonic acid in asphyxia. We are not called upon to combat the structural lesion, but a functional disorder consequent upon this, of temporary duration, but able to cause death before anatomical changes visible even to the microscope shall have been induced. It is important, therefore, to faradize the phrenic nerve, according to the rules already given in the chapter on "Asphyxia." The duration of the treatment, or of each electric application, must vary with each case. The patient should be watched unceasingly, with the battery at hand, and a weak current passed into the phrenic nerve for an instant, then arrested, at intervals which vary from the time needed for a single respiration to fifteen, thirty, or sixty minutes. When the diaphragm fails to respond to faradism, the galvanic current must be used, the circuit being closed and opened at the same regular intervals. Although all authorities recommend this treatment, few cases are recorded. Many years ago Ducheme published a case of successful faradic treatment of diaphragmatic paralysis which may easily have been diphtheritic, but such diagnosis was not made at the time.[1]

Obstetrical Paralysis.—A form of peripheric paralysis necessarily peculiar to children is the so-called obstetrical paralysis of the upper extremities, or, rather, of the upper arms. The facial muscles, or else the deltoid, supra- and infra- spinatus, biceps, and coraco-brachialis are liable to be affected. The paralysis depends upon pressure on the brachial plexus or on the facial nerves sustained during delivery, and produced either by the forceps or by the child's body against the pelvic bones. The chances of recovery are inversely proportioned to the duration and intensity of such pressure. As a rule, the prognosis is very good, but less so in paralysis of the arm than of the face;[2] and even the latter sometimes remains permanent.

It is to be remembered that this is a strictly traumatic paralysis, attended by effusion of blood among the cords of the brachial plexus. A certain amount of time is required to effect the absorption of this effused blood,—about three weeks; and during this time the arm must be kept supported and at rest. Then galvanism may be applied, with the cathode placed first over the brachial plexus, then the affected muscles. After another week the faradic current may be cautiously used, and it will then probably be able to excite muscular contractions. Obstetrical paralysis of the facial nerve is treated on the same principles. In both cases the disappearance of ecchymoses will often serve as a guide for the proper moment to begin electric treatment.

Cerebral Paralysis.—The anatomical and physiological conditions of this paralysis resemble that of compression myelitis in that the

[1] Gilles reports a case of post-diphtheritic paralysis, treated by electricity, but proving fatal through pneumonia. Rev. Elect., 1891.

[2] Ashby and Wright: Diseases of Children, 1893, p. 24.

spinal lesion, when it has developed, is a sclerosis of the white columns, —not, as with Pott's disease, circular, but affecting the pyramidal tracts in the lateral columns. With this lateral sclerosis the ganglionic cells of the anterior horns, the presumed trophic centres of the limbs, are not, as a rule, affected. Hence there is no wasting except such as is due to inaction, and therefore the indication to excite muscular contractions in order to preserve muscular nutrition is far less urgent. This, at least, is the case with adults. In children it seems—perhaps owing to the greater tendency in them to diffusion of morbid processes—that the spinal lesion does not always remain limited, but that the gray matter often becomes affected. Forster[1]—in this contradicting Erb and Seeligmüller—declares that he always finds trophic lesions in the cerebral paralysis of children. The growth of the limbs is always hindered, and faradic excitability, though not altogether lost, is diminished.

My own experience agrees with that of Forster, and, indeed, it is a general law that injury to an organism or any part of it during its epoch of growth produces a much more profound effect than if received after growth has been completed, and it is only necessary to maintain the nutrition of status. Although the paralyzed limbs do not waste much below the size already attained, slackening in its processes of growth will soon leave it markedly inferior to its fellow. Such inequality is determined even by joint diseases, where also a prolonged nervous irritation exists, tending to inhibit the remaining nervous activities of the limb. After any cerebral lesion or injury the descending lateral sclerosis also constitutes a permanent irritation, as shown by the characteristic exaggeration of the reflexes and, later, by the occurrence of tonic contractions.

Arrest of growth results not from destruction of trophic forces, but from inhibition of the nervous forces involved in nutrition. It is thus much less in extent; it never in itself acts as a bar to resumption of function in the limb. This being the mechanism of the nutritive condition, it is clear that the indication is far less to stimulate neuromuscular energy than—if possible—to allay the irritation which is holding this in abeyance. To state the indication is, at the same time, to exhibit the great difficulty of its fulfillment.

The cerebral lesions causing paralysis in children are porencephalus, localized acute encephalitis, hæmorrhage,[2] embolism,[3] and the atrophy and sclerosis, and sometimes cyst, or cicatrix, which result from such primary lesions.[4] "Changes in the blood-vessels occur at the beginning

[1] Archiv für Kinderheilkunde, 1881.

[2] Wollenberg, "Ein Beitrag zur Lehre von den cerebralen Kinder lähmungen," Jahrb. f. Kinderheilkunde, 1886.

[3] Abercrombie asserts embolism from impoverished blood; thinks hæmorrhage very rare. British Medical Journal, 1887. See also Wollenberg.

[4] Knapp, Journal of Mental and Nervous Diseases, 1887. This writer, rather oddly, supposes that the etiology of infantile hemiplegia in localized cerebral atrophy has not been generally recognized.

of the atrophy of brain-substance: the perivascular spaces are increased at the expense of the surrounding tissue and traversed by connective tissue, and in this net-work are found Deiter's cells and fat-cells. A perivasculitis is, then, the cause of atrophy, and thus is explained the occurrence of epilepsy, hemichorea, and athetosis, together with the paralysis." "There is usually an inflammatory change in the wall of the blood-vessels, which is sometimes due to an infectious agent, as in the course of one of the exanthemata."[1]

Strümpell, on the strength of two autopsies, advanced the theory that many cases of infantile cerebral paralysis were anatomically analogous to spinal paralysis, dependent on atrophy of ganglionic cells in motor areas. Kast calls this conclusion too hasty, and in his own cases of infantile cerebral atrophy finds only degeneration and sclerosis of both white and gray matter, and nowhere an encephalitic focus.[2] This, however, may easily have been the primary lesion.

Strümpell's theory, however, offers a seductive reason for attempting to treat cerebral paralysis in children by galvanism to the head, with the hope of arousing the sunken, but not altogether lost, vitality of motor cells. "Acute encephalitis in children resembles very closely infantile paralysis of spinal origin, and the paralysis is seldom as complete as in poliomyelitis. The facial muscles are rarely involved. Inflammatory changes are found in the motor area of the cortex, closely resembling those in the anterior horns in poliomyelitis."[3]

In children, even more than in adults, paralysis is occasioned not only by destruction of the nerve-elements of motor centres, but also by the shock received in these centres from lesion of any part of the brain. This shock leaves a certain amount of functional torpor, which we may often hope to dissipate by electric, especially by galvanic, stimulation. Similarly, even when the lesion is situated within motor centres, we may hope for the recovery of many elements left structurally intact among those which have been destroyed, and this recovery we may try to expedite by electricity. Nevertheless, it is still doubtful how far the passage of the electric current through the head has any beneficial effect in these cases.[4]

The marked physiological effects of this application, the giddiness and dipping of the head to the side of the anode, are very probably due to the oscillation of fluid in the semicircular canals, and thus have no therapeutic significance. No proof has yet been adduced that the absorption of a blood-clot could be facilitated by electricity. Nevertheless, what is known of the movement of liquids from the anode to the negative pole leads us to hope that the rather vague expectation of the earlier electricians may yet be justified, and that, though an increased osmotic

[1] Jendrassik and Marie, quoted by Wollenberg.
[2] Kast, "Anatomie der cerebrale Kinder lähmung.," Arch. f. Psychiat., 1887.
[3] Handford, "Cerebral Infantile Paralysis," Brain, 1886.
[4] "Galvanization of the head is always contra-indicated." Wollenberg, *loc. cit.*

streaming and quickened lymphatic circulation, the absorption of at least the fluid part of the clot may be accelerated. Clinical experiments on this problem have, so far, been confined to adults. Cases in children should offer a more favorable field, since cerebral hæmorrhage in them is not dependent upon the extensive vascular degeneration which renders an attempt at permanent cure so helpless in adults. The hemiplegic paralysis consequent upon the cerebral lesion has, however, often been treated by local applications to the limbs. But, as has been noted in regard to spinal paralysis, there is a plentiful lack of statistics and much uncertainty resulting from irregular, inadequate, and insufficiently-prolonged treatment. Two clinical facts, however, are well established. When lateral sclerosis has reached a certain grade, so that "spastic paraplegia" has developed, electric treatment rarely does any good. These cases develop within the first year or two of life, and originate in fœtal lesions of the brain; are severe, therefore, according to the extent of the latter.[1] On the other hand, the acute paralysis due to post-partum hæmorrhage has a natural tendency toward partial or complete recovery, and it has not been at all demonstrated that cases treated by electricity recover more rapidly or to a greater extent than those which have not been so treated. Systematic massage seems more powerful.

It has been already noted that many of the phenomena in the paralyzed limbs, including a part of the paralysis, are due not directly to the cerebral lesions, but to the secondary descending sclerosis. This, on the other hand, seems to be in some way connected with the loss of nerve-currents which should, normally, be incessantly traversing the motor tracts from the ileo-motor centres of the hemispheres. As we can maintain to a considerable extent, the nutrition of muscular fibre, by supplying an artificial substitute for its normal stimulus to contraction, so, it would seem, we might arrest the nutritive degeneration of the motor tracts, could we traverse them by an electric substitute for the nerve-currents initiated by volitions. From this point of view it would be advisable to place the anode upon the vertex of the head, the cathode over different stations of the spinal column in succession, from the nape downward, and so traverse the entire cerebro-spinal axis by a weak constant current.

It is important—that is—that the current which finally reaches the nerve-tracts should be weak. But there is so much resistance to be overcome before the current can penetrate to the nerve-centres that the amount to be passed to the electrodes from the battery must not be too small. With very large electrodes, so as to secure the maximum of quantity with the minimum of surface irritation, the sensibility of the patient may be a sufficient guide for the number of milliampères that should be used. Theoretically, central stimulation by means of local faradization of paralyzed limbs should be of little service, unless by a

[1] This pessimistic view is, however, disputed by some modern clinicians.

means presently to be mentioned in connection with hysteria. Yet this is the form of electric treatment most commonly employed, on account of the cheapness of the apparatus required and the agreeable impression made on the imagination when inert limbs are set into vigorous motion. Many writers maintain, for cerebral as for spinal paralysis, the necessity of producing artificial contractions in the inert muscles in order to preserve their nutrition. On the other hand, the central stimulation of static electricity might be of very great service. It has not as yet been tried to any extent.

All writers advise that electric treatment of cerebral paralysis be re-inforced by energetic efforts to elicit voluntary innervation. Many delicate psycho-physiological problems are involved in such efforts. The initial phenomenon of a motor act is a mental conception of the end to be attained by it.[1] Hemiplegics have not been sufficiently interrogated in regard to their mental states, as these involve conceptions of acts they would like to perform, but know, or believe, to be impossible. Some startling discoveries have been made by means of the hypnotic suggestion of hemiplegics, which would lead to the inference that artificially-induced mental states have more selective power than any other agency upon nerve-elements left intact after a cerebral injury, and that a much smaller number of these than normally function are really absolutely necessary for the conveyance of a voluntary impulse.

It is difficult to induce children to make voluntary efforts to move paralyzed limbs. But, on the other hand, children are very susceptible to hypnotic suggestion; and it is possible that a systematized therapeusis of cerebral paralysis will some day be developed upon the basis of this psycho-physiological fact.

Hysterical Paralysis.—Children, though much less frequently than adults, are occasionally liable to that form of cerebral paralysis which is functional and known as hysterical. Local faradization is the well-known and heroic remedy for this affection, to which we may now probably add static electricity. The latter acts as a central stimulant by irradiation; but faradization, which causes lively contractions of hysterically-paralyzed limbs, probably acts not only as a physical stimulant, but also through mental suggestion. Limbs of whose incapacity the patient had been profoundly convinced are seen, under the influence of the current, to move and to simulate all desired combinations of activities. The observation tends to dislodge the previously fixed idea of immovability: new mental conceptions are formed of the different positions into which the limb needs to be placed to effect such and such a purpose, and the dawning conception itself constitutes the initial stage of a voluntary action. In this way also, as already hinted, may faradization be useful in organic cerebral paralysis,—the mental conception expressing itself through nerve-elements surviving in the midst of the

[1] William James: Psychology.

destruction of many others. Vulpian advises local faradization in cerebral paralysis, to stimulate the nerve-centres. Charcot strongly advocates static electricity in hysteria.[1]

Spastic Paralysis.—Spastic paralysis, hemiplegic or monoplegic, has an especially unfavorable prognosis, because dependent on a lesion initiated during fœtal life, and generally far progressed before the case comes under medical observation. Ferguson reports a case which is typical for this form of paralysis. The child, who died when 3½ years of age, began to have stiff legs when only a month old, and the characteristic rigidities were well marked at 2½ years. There were also slight internal strabismus, nystagmus, and, for six months, epileptic attacks. At the post-mortem were found sclerosis at the upper end of the fissure of Rolando, extending to the ascending parietal convolution; atrophy of cortical cells at this level; band of degeneration through posterior part of internal capsule, pons, and medulla, and thence through the lateral tracts of cord.[2] So Marie observes: "In the majority of cases the lesion is primarily an arrested development of the brain, following an inflammation which had occurred during fœtal life; it involves the cortical motor centres, and results in the incomplete development of the pyramidal tract."[3]

It may easily be inferred that little could be expected from electricity or any other therapeutic agent in such a condition. Erb and Seeligmüller both pronounce electricity useless. Rupprecht, however, insists that the constant current to the spine, combined with the use of warm baths, may give excellent results in such cases, and quotes ten cases of improvement.[4] Sinkler advises galvanization over the spine, but adduces no proof of its utility.[5] Marie advises massage and passive movements, warm baths, galvanism to the medulla, and cautions, perhaps superfluously, against the use of faradism.

Peripheric Paralysis.—"In the records of multiple neuritis, excepting the form produced by diphtheritic poison, no cases of children are included."[6] It is, however, probable that some cases diagnosed as poliomyelitis are really cases of multiple neuritis. Dr. H. D. Chapin[7] has described four cases of atrophic paralysis resembling ordinary infantile paralysis except in the presence of sensory symptoms and a steady progress toward recovery. Starr,[8] habitually so skeptical about the therapeutic value of electricity, nevertheless considers this agent as the first in importance in the treatment of multiple neuritis. It increases the process of nerve regeneration, re-establishes the conduction of im-

[1] Revue de méd., 1881.
[2] American Journal of Obstetrics, 1891.
[3] P. Marie, "La paral. spinale spasmod. infantile," l'Union méd., 1891.
[4] Volkman's Klin. Vorträge, No. 198.
[5] Sinkler, "Different Forms of Paralysis in Young Children," American Journal of the Medical Sciences, 1873.
[6] Mills, New York Record, 1879. (Two cases.) See St. Barth. Hospital Reports, 1877.
[7] "Painful Paralysis in Children," New York Medical Record, 1887.
[8] Starr, *loc. cit.*

pulses in the regenerated nerve, and maintains the nutrition of muscles by exercising them. For the first purpose is advised a mild current of galvanism, in daily *séances* of ten minutes, to each limb. For the second purpose the induced current, with one pole over the nerve-trunk and pressing the other over the skin of the limb. For the third purpose the muscles must be contracted by the faradic or the interrupted galvanic current.

Facial Paralysis.—Facial paralysis occurs in the child not only as on accident of parturition, but, as in the adult, after exposure to cold, —a rheumatic paralysis, often dependent on effusion into the nerve-sheath. The treatment is naturally the same for children as for adults, —a daily application of the constant current, followed by a brief *séance* of contractions under interrupted galvanism, since faradic contractility is lost. The treatment, as for other forms of neuritis, is undoubtedly most valuable. The electrodes are placed in front of the ear, or at the styloid process, and over the cheek, respectively.

Paralysis of Serratus Magnus Muscles.—A rather frequent[1] form of peripheric paralysis in children affects the serratus magnus muscle. This was treated by Duchenne with faradism;[2] but at the present day the combination of galvanic and faradic treatment would be preferred. The case related in the foot-note occurred in an adult.[3]

Pseudo-hypertrophic Paralysis.—The same gloomy prognosis must, so far, be given for pseudo hypertrophic paralysis as for spastic paralysis, and also for the juvenile forms of progressive muscular atrophy. Diseases which express fundamental errors of development during fœtal life cannot be amenable to agencies directed only against errors of nutrition.

Pseudo-paralysis.—Finally, however, must be considered, but only until the diagnosis shall have been made, the form of paralysis occasionally observed in severe forms of hereditary syphilis,—the pseudo-paralysis of Parrot.[4] It is an osteitis of the epiphysis, associated with specific infiltrations of the osseous tissues. Comby[5] calls this affection very rare and difficult to diagnose. It has been, though unpardonably, confounded with infantile paralysis. Its essential character is an inertia, an impotence of the limb (the affection is usually monoplegic) similar to that produced by fractures or dislocations. The faradic contractility is

[1] Soltmann, *loc. cit.*

[2] Electrisation localisée, 1861.

[3] A seaman aged 39 engaged in lamp-lighting, and after six months observed weakness of arm; the ribs bulged; top of right shoulder one and one-half inches higher than the left; inferior angle of scapula two and one-half inches higher and one and three-fourths inches nearer to spine than left; projection backward one inch from surface. There was no response to the faradic current, but the treatment was conducted with this: cold douches; rest to arm, which was supported in a sling; quinine and strychnine internally. In two months very great improvement. Woodman, British Medical Journal, 1875.

[4] Archives de Physiol., 1871, 1872, 1876. Also Gaz. des hôp., 1882. Also Troisier, Progrès Méd., 1883.

[5] Progrès Méd., 1883. Also case of Damaschino, Gaz. des hôp., 11 Mai, 1883.

preserved. There is sometimes bony crepitation. The circumference of the articulation is increased. According to Parrot, the disease is almost invariably fatal, but Millard and Roques relate two cases of recovery.[1] The diagnosis having once been carefully made and the pseudo-paralytic character of the affection recognized, all questions of electric application, of conrse, at once disappears, and the child is put upon antisyphilitic treatment.

Convulsive Affections (Kinetic Neuroses).

The application of electricity to such diseases as chorea, epilepsy, tetany, and torticollis is an empirical experiment for which little pretext can be found, or is, indeed, often alleged. But, as in all cases in which electric treatment is used it has so far been found impossible to exactly deduce the expected or observed therapeutic effects from such physiological actions of electricity as are known, this defect in theory would not be fatal were the results of experience thoroughly satisfactory.

Chorea.—Thus, the motor spasms which characterize this disease seem, to some physicians, to invoke the " sedative influence " of galvanism. This sedative influence is inferred from the phenomena of electrotonus, and especially from the diminished area of excitability in a nerve around the positive pole conveying a galvanic current. " Electricity," observes Poole, " is a paralyzing agent."[2] But it is only by analogy, and not directly, that, from the phenomena of electrotonus on a nerve-fibre, we can infer a " sedative influence " upon an " irritation of ganglionic nerve-cells." The nature of this irritation is itself only dimly suspected. In some way a defective nutrition of the elements of nerve-centres leads to a defective retention of the centrifugal or motor force generated in them. Chorea is undoubtedly associated with defective nutrition of nerve-centres ; the " motor irritability," or erethism, consists in the irregular and incessant nervous discharges which should, normally, be deferred until liberated by the stimulus of volition. For it is the voluntary system of muscles which are mainly affected. Did galvanism of the jerking limbs act by producing an electrotonus in their nerves (for this purpose only the polar method should be used, and the anode applied to the limb), it could only reduce the conductivity of nerves to the nervous discharge, leaving unaffected the irritation of the ganglionic centres. But, on the other hand, the anodal depression of excitability lasts only while the current is passing ; when it ceases, the anodal nerve-segment becomes relatively excited.

These considerations are cited by Moll as helping to show that our physiological knowledge about electricity is not only small, but of little value in the explanation of its clinical effects.[3] De Watteville calls

[1] Quoted by Comby, *loc. cit.*
[2] Medical Record, 1881.
[3] Berlin. Klinik, 1891.

"futile" the attempt to explain electro-therapeutics by the illy-understood electrotonic effects of the galvanic current on exposed nerves.[1] And Ziemssen, advocate of electro-therapeutics though he be, declares that its "physiological side is very unsatisfactory, its therapeutic much more developed."[2] In other words, it is easier to treat patients by electricity than to understand why we do it! However, the same assertion may be made of most remedial agents for disease, and other forms of electricity than galvanism are used for chorea; and the application is made elsewhere than to the limbs.

Benedict declares that galvanism "is one of the most valuable modes of treatment in chorea minor. It cures, almost without exception, even cases which have resisted all medication." He applies the galvanic current to the spine in either an ascending or descending direction, and "cures not only the motor, but the psychic and all other symptoms of chorea."[3]

Benedict quotes three cases:—

1. A girl of 10. The chorea had lasted six weeks, and was cured in six sittings. Two years later, however, in a relapse, several weeks were required to effect a cure.
2. Boy of 11. Galvanism to the spine effected great improvement in a week.
3. Also a boy of 11. Cured.

In 1853 Gull declared that in the treatment of chorea he obtained "remarkable and sometimes astounding results with electricity."[4] "These are probably due to a direct stimulation of the blood-vessels of the nerve-centres, which thus produces in these a more vigorous circulation." Hughes,[5] in a digest of 100 cases of chorea, reports static electric treatment in 14. Of these 9 were cured. Some were so severely affected that they could scarcely be held on the insulating-stool, but after two or three *séances* were able to sit up by themselves. C. H. Hughes[6] regards chorea as a neuratrophia, and applies a descending electric current to the spine in order to "stimulate the motor areas." A. H. Bennett,[7] on the other hand, uses galvanism in chorea to modify nutrition. "It is sedative from its effects on the molecular and trophic elements of the tissues, and relieves motor and sensory superexcitability." Henoch uses galvanism, among other remedies, for chorea,[8] but for exceptional cases. Rockwell considers central galvanization the cure for chorea. A case is related where this treatment was useful even in post-paralytic chorea[9]:—

A boy of 8 had, at 7, had an attack of acute articular rheumatism with endocarditis, followed by paralysis, evidently from embolism. Then chorea, which still persisted a year later. Immediate and steady improvement under central galvanization, and the patient was discharged cured.

[1] Med. Times and Gazette, 1882. [2] *Loc. cit.* [3] Elektrotherapie, 1874, p. 255.
[4] Guy's Hosp. Reports, *loc. cit.* Gull's cases of electrical treatment of paralysis have already been quoted.
[5] Guy's Hosp. Reports, 2d series, vol. viii.
[6] Weekly Med. Review, Chicago, 1884, ix, p. 168.
[7] "Principles of Electro-therapeutics," Brit. Med. Journ., 1884.
[8] Berlin. klin. Wochen., 1883, xx.
[9] Journal for Mental and Nervous Diseases, 1882, p. 550.

Dana reports eight cases of chorea treated by galvanization of the brain. The polar method was used; a large sponge electrode upon flexible brass, connected with the positive pole, and placed over the head above the ear, the hair having been thoroughly wetted. The other electrode was held in the hand. A stabile current of from three to six Stöhrer cells was passed from three to six minutes. Improvement followed each *séance*,[1] and continued twenty-four to thirty-six hours. The average duration of the symptoms was thirty-four days, of treatment twenty-five days, as compared with six or eight weeks in thirty other cases treated chiefly by arsenic.

Such treatment is, of course, based on the theory that chorea is due to a lesion, functional or organic, of the brain. In another paper on chorea Dana notes that the disturbance of mobility includes not only spasm, but paresis, and attributes the disease to some agent, at once irritating and depressing, which affects the postero-lateral parts of the central gray matter of the cord, the basal ganglia, cortical motor areas, and pyramidal tracts. There is an active hyperæmia, often minute hæmorrhages. Chorea is hardly to be called a neurosis, but rather a specific infectious or toxic disease, attacking a definite area of the nervous system.[2] Notwithstanding the evidence of organic lesion adduced by the author, perhaps because of it, he reiterates his recommendation to treat chorea by weak anodal galvanism of the brain.

There are many reported cases of chorea, terminating fatally, where capillary embolisms were found in the corpora striata and optic thalami.[3] In choreic dogs Wood has found motor cells of the cord shriveled, and many lymphoidal cells infiltrating the gray substance. When in such animals the spinal cord was cut, the choreic movements continued in both the front and hind legs, showing therefore an independence of the brain, and pointing to an origin in the cord. When the sciatic nerves were laid bare and a galvanic current was passed through them, the movements in the limb were at once inhibited. The author attributes this arrest to inhibition of the motor cells of the cord, but the crucial experiment of applying the current after section of the cord does not seem to have been performed.[4] The cerebral symptoms in choreic patients indicate that the cells of the brain are also affected.

It is not claimed that organic lesions exist in all cases of chorea, but that in all cases the ganglionic cells of motor areas are affected,—at first in a so-called functional manner, producing no visible structural altera-

[1] Med. News, Nov. 17, 1883. Wollenberg says that the brain and especially the basal ganglia are probably the seat of the lesion of chorea. ("Path. anat. der chorea minor," Arch. f. Psychiat., 1891.)

[2] Arch. Pediat., 1888. Chorea, spasmodic tic, and hysterical spasm in children.

[3] In experiments by Angel Money and others starch and carmine were injected into the common carotid in order to produce minute embolisms in the brain, and choreiform movements developed. The author observes that chorea is due to defective nutrition similar to that causing paralysis, but less in degree.

[4] "Basal Pathology of Chorea," Bost. Med. and Surg. Journ., 1885, and Therap. Gaz., 1885.

tion, but resulting in this at last, should the disease be prolonged. The faradic current has also been used in chorea, more especially when associated with hysterical symptoms. Merklen relates the following case[1]:—

A girl, 16 years old, had a frightful dream, and the next morning had right hemichorea, together with hemianæsthesia to cold, heat, pain, and touch on the same side. All the special senses—sight, hearing, tase, and smell—were also involved in the hemianæsthesia. Vulpian electrified the skin of the anæsthetic and choreic arm with the faradic brush, under which, after a few minutes, sensibility returned not only in the arm, but over the entire side, and at the same time the choreic movements diminished. After a daily *séance* for seventeen days the girl was cured.

Vulpian advises this powerful peripheric excitation for the sake of its influence upon the nerve-centres.[2] Rockwell also uses general faradism, though preferring central galvanization. According to the theory advocated by Onimus, that faradization by reflex stimulation dilates blood-vessels, this current might be indicated where there was reason to suppose anæmia of the nerve-centres, preceding or consecutive to an hyperæmia, or even entirely replacing it.

There is far from being a general consensus of opinion in regard to the value of any electric treatment of chorea. Ross does not mention it.[3] Henoch "can say little in favor of the constant current, of which others speak so highly."[4] Nevertheless, he reports two cures of "electric chorea" by galvanism administered by Remak.[5] Gowers remarks that "electricity has been employed in various ways, especially the voltaic current to the spine; and it is very doubtful whether the agent has any real influence. The spasms are usually lessened for the moment by the passage of the current through the limbs, but the effect quickly passes away."[6] Hutchinson observes that few cases of chorea receive any benefit from electricity.[7] The following is the only case of chorea treated by electricity which is reported in the *Index Medicus*[8] since 1889:—

A boy of 13 was attacked with choreiform movements in both limbs and face. The spasms were so severe as to frequently confine him to bed. The disease lasted, in spite of much treatment, for three years. Electric treatment was used in the following way: A continued ascending current was applied to the spine three times a week for two weeks, then interrupted for a week. Then eight daily applications were made, then two a week for a month. Each sitting occupied eight minutes, and from 6 to 12 milliampères were employed. Twenty-six sittings in all were required to effect the cure.

Static electricity, used for its tonic effect on the nerve-centres, seems to have been, so far, little tried in chorea. It is, however, strongly recommended by Blackwood, among other indications for the same remedial agent.[9]

[1] La France médicale, 1882.
[2] He advises it even in recent hemiplegia, as has been already mentioned.
[3] Diseases of the Nervous System.
[4] Diseases of Children.
[5] Berlin. klin. Wochenschr., 1881.
[6] *Loc. cit.*, chapter on Chorea.
[7] "Practical Electro-therapeutics," Med. Reg., 1887.
[8] *I.e.*, in an isolated way.
[9] "Static Electricity," Phil. Med. Times. 1881.

Other remedies recently used for chorea, in place of the well-tried and reliable arsenic,[1] are: antipyrin,[2] chloral,[3] conium,[4] chloroform.[5]

Localized Clonic Convulsions.—The localized convulsions to which young children are especially liable, such as the salaam tic and "head banging,"[6] does not seem to have been benefited by electricity. Facial tics in older children are also rebellious. The following case by Berger, however, offers encouragement for the electric treatment of facial spasm in younger subjects:—

The patient was a medical student, aged 22. After a cut received in a duel, clonic spasm set in of the orbicularis and frontalis muscles, and lasted for hours. Then a short intermission, after which the spasm recurred, and this condition persisted for five months. Then galvanic treatment was instituted, by applying the stabile anode over the left infra-orbital nerve, while the cathode was held in the hand. The spasm diminished at once, and after five minutes' application of the current it ceased entirely; but two minutes after cessation of treatment the orbicularis began to twitch, and then the cramp extended and resumed its former severity. At the next *séance*, therefore, the mode of application was changed. The anode was placed on the occiput below the protuberance, the cathode was held in the hand, and the current passed for ten minutes. The spasm ceased at once, and did not return. Six days later some relapse occurred, which was again, and this time permanently, cured by galvanism.[7]

The author attributes the cure to an electrotonic action of galvanism upon the morbid excitability of the medulla. Jewell insists that for irritative affections the positive pole should always be placed at the seat of the irritation; the negative pole not at an indifferent point, but so that the real seat of the disease is included in the track of the cur-

[1] "Arsenic is a specific in chorea." Sawyer, "Brain," Med. Rev., 1888.

[2] Bouveret relates a case of "electric chorea," a very rare disease, where a girl of 15, after violent emotion, was affected with synchronous convulsive movements, of lightning-like rapidity, of muscles, trunk, head, and four limbs. The face and attitude expressed great fear, and the convulsive movements were comparable to those of the muscular shock which fear causes. The affection disappeared in four days under treatment by antipyrin, of which the patient took 60 grains daily. (Lyon méd., 1890.) Another case is related in same journal, in 1888. But the antipyrin treatment, though successful, required to be pushed to 45 grains a day, and lasted from December 10th to January 21st,—thus forty-two days. There was, at first, apparent cure of a slight chorea in five days; then relapse, in a much more aggravated form. See also case by Anderson, —cure in twenty-one days, under antipyrin and rest in bed. Lennox found, in thirty-three cases so treated, an average duration of forty-five days. Legraux and Dupré (Revue mens. des mal de l'enfance, 1888) declare that there is no more rapid way of curing chorea than by antipyrin. They report one case of two years' standing, and in nine days on an average 3 grammes daily were used

[3] Bastian (Lancet, 1889) has treated severe chorea by sleep procured and maintained by 20-grain doses of chloral, so given that the patient is only awake half-hour at a time to receive nourishment. Especially applicable where there is no heart disease, where the choreiform spasms are severe and continuous, and have lasted a long while. So also Joffroy (Progrès méd., 1885). This author admits no relationship between chorea and traumatism, and thinks joint manifestations in chorea are neurotic arthroses.

[4] Mills (Polyclinic, 1884) has successfully treated a very severe case of chorea by fluid extract of conium (combined, however, with Fowler's solution,—5 minims of each every two hours).

[5] Bostock reports a very acute case treated by chloroform. The patient, a girl of 10, was unable to speak or swallow, had lost control over sphincters, and suffered from bed-sores. A few drops of chloroform kept her quiet for two hours, were then repeated, and thus for thirty hours almost continuously. The patient at once began to improve, and finally entirely recovered.

[6] Hadden, St. Thomas's Hosp. Reports, 1890; Putnam Jacobi, Archives of Medicine; also Caillé, Trans. American Pediat. Soc., 1889.

[7] Berger, Neurol. Centralblatt, 1883.

rent.[1] The application should be made once or twice in the twenty-four hours.

Tetany.—This spasmodic affection of the extremities was at first supposed to be peculiar to nurslings,[2] but recently cases have been observed in older children and also in adults. There is marked increase of reflex irritability and also of the electric excitability of peripheric nerves toward galvanism and faradism. Ka S appears early, and with very feeble currents Ka S Te appears, and even An O Te.[3] Thus electric applications may aid, like Trousseau's phenomenon, in establishing the diagnosis. But according to Weiss these applications are of little service in the treatment.

Electric hyperexcitability has been observed by Fränkel[4] and by Hoffman.[5] This physician tested his own ulnar nerve during thirty-three days, and found variations in reaction only to the extent of 1 milliampère with galvanism, and of 14 millimetres with the faradic current. He then tested nineteen patients with tetanie, and found almost constantly an increase of galvanic excitability. In forty-eight trials this existed without increased faradic excitability, while four times the latter was increased, but not the former. Kussmaul found increased excitability to faradism and galvanism. Oppler, however, has carefully studied a case in an adult of 20, subject to attacks during five years, and whose father and five brothers were similarly affected. The spasm was confined to the right leg. The quantitative reaction to numerous electrical tests was exactly the same for the affected and unaffected leg. "Therefore," observes the author, "notwithstanding the many observations of Erb, Kussmaul, and Weiss, it cannot be held that electric hyperexcitability is, without exception, a symptom of the muscles affected in tetanie."[6]

The mechanical excitability of both muscles and nerves, sensory[7] and motor, was also increased.[8] According to Baginsky, the phenomena of tetany depend on an idiopathic muscular contraction. The electric hyperexcitability observed by the writers just quoted does not prove an affection of the central nervous system. But this has been inferred from the symmetry of the spasm. It is precisely this symmetry, however, which Baginsky denies, and upon the lack of it bases one argument for an idiopathic muscular disease. In one of his cases, at the right thigh, the flexors and adductors were thrown into spasmodic contraction by the slightest touch, while on the left side the extensors of the leg were similarly affected. The symptoms began and ended with an attack of indi-

[1] "New Method of Using Galvanism," Neurological Review, Chicago, 1886.

[2] Trousseau, Clinique de l'Hôtel-Dieu.

[3] Weiss, "Tetanie," Sammlung klin. Vortrag, No. 189, 1881. See also Erb, who found the greatest electric excitability at the moment of maximum spasm.

[4] Deutsches Arch. f. klin. Med., Bd. xliii.

[5] Hoffman, "Vorhalten der sensibilen nerven bei der Tetanie," Neurol. Centralbl., 1887, vi.

[6] "Beitrag zur Casuistik der Tetanie," Deut. Arch. f. klin. Med., 1886.

[7] Hoffman, Deutsches Archiv f. klin. Med., 1888.

[8] See also Schultz, "Tetanie—Increased Reflex and Electric Excitability," Deutsch. med. Wochen., 1882, viii.

gestion, and Baginsky attributes them to some poison absorbed from the digestive tract and circulating in the blood.[1]

Hadden, reporting five cases, thinks that tetany is due to a temporary derangement of functions of the pyramidal tract. It is prevalent in children,[2] because this system of fibres is in a period of active development, and therefore more liable to functional disturbance.[3]

Cheadle, in an excellent review of the subject, calls laryngismus, tetany, and convulsions the positive, comparative, and superlative degrees of the convulsive state in children,—a state of motor erethism especially associated with rhachitic malnutrition.[4] There is no disease of the governing cerebrum, but undue excitability of the motor ganglia of the cord. The author does not, however, attempt to overcome this excitability directly, through the "sedative influence" of galvanism; but indirectly, through dietetic remedies addressed to the nutrition—suitable diet and codliver-oil—and other typical treatment of rhachitis.

Hoffman (*loc. cit.*), who admits an "erethism in the gray substance of the anterior and posterior horns of the cord" as the basis of tetany, employs galvanism with good effect, but uses also many drugs.

The close dependence of tetany upon affections which exhaust the nutrition, by causing morbid drains from mucous surfaces, has led to the theory that the nervous irritation is due to absorption of putrefactive substances from such surfaces. For it occurs not only after diarrhœa, but also after constipation; also in scarlatina, phthisis, and ulcerative stomatitis.[5] Any view of tetany as due to the circulation of poisons in the blood, and thus analogous to tetanus, as its name implies, certainly tends to discourage electric treatment.

An interesting and novel modification of this view ascribes tetany to the mucin now supposed to accumulate in the system whenever, through disease, atrophy, or extirpation, the functions of the thyroid gland are in abeyance. Von Eiselberg[6] cites experiments in animals where total extirpation of the thyroid was always followed by tetany. This accident was prevented if only half the gland was removed and reimplanted in the abdomen before the removal of the second half.

"Tetany and myxœdema are closely related; . . . myxœdema is the chronic, tetany the acute form of mucin intoxication." This theory is, again, entirely inimical to galvanic treatment, unless, indeed, the latter be used as a symptomatic palliative for cramps unusually severe

[1] "Ueber Tetanie der Säuglinge," Deutsch. med. Wochenschr., Berl., 1886.

[2] But not confined to them. Adult cases are reported by Jamieson, Australasian Med. Jour., 1886; James, Edin. Med. Jour., 1891; Tannahill (man of 29 years), Brit. Med. Jour., ii, 1885.

[3] St. Thomas's Hospital Reports, 1886. See also Escherich International Medical Congress 1890, ii.

[4] Lancet, 1887, i, 919: "When such affections occur in adults, the nutrition has also been previously impaired by some drain, as lactation, pregnancy, diarrhœa, or hæmorrhage." See also Lyman, Tr. Asso. Am. Phys., 1886: "A disorder depending on acquired irritability of nervous and muscular organs."

[5] Carpenter, "New Theory of Tetany," Tr. Ass. Am. Phys., 1889.

[6] "Ueber Tetanie nach Kropfoperation," Wien. med. Wochen., 1890.

or generalized.[1] In such case, from analogy, the "nutritive" effect of galvanism should be sought for the spinal cord, the "sedative" for the contracted muscles. For the first indication, a large anode should be placed at different levels successively along the spine; for the second, the same anode should be moved along the limb, but left longest in place at the point where the nerves enter the affected muscles. The cathode can be held in the hand, or placed at the sternum.

Still another cause of tetany seems to have been found in dilatation of the stomach, with consequent diminution in the absorption of water into the system and probable absorption of putrefactive products.[2]

Torticollis.—Wryneck is a fairly common affection in childhood, but dependent on very varying conditions; thus, "from error of fœtal development,[3] when it is, of course, congenital; from injuries at birth;[4] from hæmatoma,[5] or from suppuration in the neck, burns, or similar injuries. Finally, it may be spasmodic, due to central- or peripheral-nerve lesions or reflex irritation."[6] And Forchheimer has described an intermittent form of clonic torticollis caused by malarial poisoning and entirely cured by quinine.[7] In congenital wryneck, where there is not only a tonic contraction, but structural shortening of the sterno-cleido-mastoid, and sometimes of the trapezius as well, division of the muscle is necessary.[8] In acquired torticollis, either tonic or clonic, excision of the spinal accessory nerve seems to have proved a far more successful kind of treatment than any form of electricity.

The following cases are interesting as showing the effect of electricity before and after the operation:—

The first patient was a porter who had carried trunks on his right shoulder for fourteen years, and had acquired a clonic rotatory movement of the head toward the left. Electricity was applied for seven weeks (we are not told by what method), but the result was that the rotation became permanent. Two-fifths inch of the spinal accessory nerve was excised, causing paralysis of the sterno-mastoid and trapezius; but this was cured by the local application of faradic electricity.

In the second case no electric treatment was used until after the surgical operation, when one inch of the nerve was removed. Then, again, the resulting paralysis was cured by faradic electricity.[9]

[1] As in a case by Godlee, in a boy of 9, where the spasm affected the jaw, muscles of back, and abdomen. The boy was unable to walk, and the spine arched considerably. The recovery was gradual, but spontaneous. (Medical Times and Gazette, ii, 1884.) See also Schlesinger, "Tetanie Fräge" (Allg. Wien. med. Zeitung, 1890), who advises galvanism for symptomatic treatment when no clear causal indications can be found.

[2] Frankl-Hoehwart, Die Tetanie, 1891; Bouveret et Devie, Revue de méd., 1892.

[3] Guyon, Dict. Encyc. des Sciences, 1887.

[4] Peterson thinks that a muscle may have become shortened during fœtal life from malposition, then rupture during birth from sudden stretching. Advises treatment by *gradual* stretching, then myotenotomy. Arch. für klin. Chir., 1884.

[5] Whitman (Medical News, 1891) thinks hæmatoma and torticollis not always associated.

[6] Ashby and Wright, *loc. cit.*, p. 647. These writers quote Golding Bird as attributing wryneck to a cerebral lesion analogous to the cord-lesions in infantile paralysis. Guy's Reports, 1890.

[7] Arch. Pediat., 1887.

[8] Barnes relates a successful case—congenital—operated in this way when the boy was 8 years old. British Medical Journal, 1889.

[9] Sands, Annal. Anat. and Surg. Brooklyn, 1883, vol. viii, p. 277.

Other cases of the same operation are still in adults. Thus Richardson [1] operated on a woman of 48, where the muscular contraction had existed four years; Schwartz,[2] in a patient of 26, in whom a very painful clonic spasm lasting six months had resulted in a permanent contraction of the muscle. In a boy of 14 a spastic torticollis seemed to be due to a faulty position of the eyes, so that binocular vision was only obtained by tipping the head to the right. This case was greatly improved by dividing the superior rectus tendon of the left eye, which had spasmodically contracted and raised this eye above the level of its fellow.[3]

Richardson observes that the sterno-cleido muscle is only partially paralyzed by section of the spinal accessory nerve, since this muscle also receives filaments from the cervical plexus. These last filaments have also been divided in a bold operation by Keen.

Whatever the operation, however, some paresis of the muscle remains, which requires treatment by faradic electricity. Guyon used this, without operation, to the muscles antagonistic to the contracted sterno-mastoid. In children, apart from the congenital cases, the most frequent cause of torticollis is rheumatism. For this the faradic brush, passed vigorously over the affected part, is an excellent remedy. Or, again, static electricity. "For relief of contracted muscles heavy electrical sparks have been found to surpass any other treatment."[4]

In most cases of torticollis, however, where operations on the spinal accessory have been performed, the patients had been already previously submitted to much other treatment, including galvanism, which had evidently failed.[5] Subsequent to the operation, the faradic current has usually been employed to restore the power of the partially paralyzed muscles. The nerve is sometimes stretched; sometimes, if the lesser operation fails, is excised.

The conclusion may be drawn that cases with structural alteration, organic shortening of the muscle, may sometimes yield to massage and systematic stretching, but will generally require myotomy, followed by faradization. Nevertheless, that in such cases the nutritive influence of both voltaic and static electricity will be useful, both before and after operation; that when the spasm—tonic, or more especially clonic—is due to a nervous irritation, idiopathic or reflex, operation on the nerve will usually be required if the case be of long standing. But acute cases, usually attributable to some rheumatic influence, may be expected

[1] Boston Medical and Surgical Journal, 1888.

[2] Bull. de Soc. de chirurgie de Paris, 1886, vol. xii, p. 81.

[3] Wadsworth, Boston Medical and Surgical Journal, 1889.

[4] Graydon, Times and Register, 1890. So also Ranney, "Static Electricity in Medicine," Phys. and Surg., Ann Arbor, 1887.

[5] Thus three cases by Southam, British Medical Journal, 1891. Petit relates twenty-four such cases, the tonic spasm being limited to the sterno-mastoid. Eighteen cases successful. Orthopædic Review, 1891. Renton, Glasgow Medical Journal, 1889 (nerve stretched). Page, British Medical Journal, 1888 (nerve stretched).

to yield to the faradic brush or static electricity. The former may suitably be applied two or three times a day.[1]

Epilepsy.—The grand convulsive disorder, epilepsy, has rarely been subjected to electric treatment with any shadow of success. The following cases are therefore interesting. The anode was applied over the central convolutions of the brain, as in Dana's treatment of chorea. A current of 4 milliampères was passed. One patient remained at first two years, then sixteen months, without an attack; second, only three attacks in eighteen months. The third patient had been having an attack once a week for eighteen months; but after three months daily electrization remained free for ten months, then had attacks at intervals of three months.[2]

Enuresis.—There is one troublesome affection of childhood which has been submitted, empirically, to electric treatment a great deal, but concerning the results of this treatment opinions continue to be much divided. I refer to incontinence of urine. It is inevitable that much uncertainty should surround the treatment of enuresis, since its pathogeny is still involved in doubt. On the supposition that the incontinence depends on an hyperexcitability of the vesical mucosa, remedies are administered which are supposed to diminish the sensibility of this membrane. On this account the "sedative" influence of galvanism is involved, but mediately, since many considerations oppose the immediate application of a galvanic electrode within the cavity of the child's bladder. Or, there is said to be a "weakness of the vesical centre in the spinal cord," and galvanism is advised to increase the activity of this centre.[3] On the other hand, enuresis is as often explained by a convulsive excitability of the detrusor muscle or by weakness of the sphincter.[4] In the first case the galvanic current has been recommended, passed from the lumbar spine to the perineum. In the second the faradic current, applied in the same manner. Ultzmann advises the most systematic use of electricity.[5] "Enuresis nocturna," he says, "is due to a disproportion between the force of the detrusor and the sphincter, the innervation of the latter muscle being defective. Enuresis diurna is due to deficient development of the sphincter muscle." The author advises indirect irritation of the sphincter vesicæ from the rectum. The hæmorrhoidal nerves, and especially the median and inferior from the pudendal plexus, supply the lower segment of the bladder, as well as the external sphincter ani. One electrode from an induction apparatus should be inserted in the rectum; the other, the sponge electrode, placed on the raphé perinei. A weak current, just bearable, should be passed for five to ten minutes, and the *séance* be

[1] Williams relates a case of intermittent torticollis cured by toxic doses of gelsemium (gtt. xxiii ter de die) after myotomy had failed to relieve. The patient was a young man of 24. The spasm occurred as soon as he tried to move or walk. Medical News, 1889.

[2] Medical Times and Register, 1891, vol. xxii, p. 95.

[3] Eardley, *loc. cit.*

[4] Von Limhauer, Allgemeine Wien. med. Zeitung, 1890.

[5] Verlesungen ueber Krankheiten der Harnorgane. Wien., 1891, p. 147.

repeated daily for four to six weeks. Baruch, on the other hand, has tried this method, and claims to have had no good results, and much prefers progressively increased doses of atropia in order to paralyze the detrusor muscle.[1] Many cases, however, are reported of successful treatment of enuresis by faradism. Day, in order to stimulate "the weak muscular coat of the bladder," passed the faradic current from the sacrum to the pubes for ten minutes daily. There was immediate improvement, and the patient, a girl of 7, was soon permanently cured. Three similar cases were cured by adding belladonna treatment to the faradic.[2]

Janin mentions a case, in a girl of 15, where complete cure was effected by placing one electrode in the urethra, the other on the thigh.[3] I myself recall at least one case, in a girl of this age, where the faradic current effected a cure, being passed daily from the lumbar spine to the pubes. Settin cured a case in a boy of 7, incontinent from birth, the urine dribbling away constantly; after two months' treatment the bladder could be controlled thirty minutes; finally, the patient was completely cured.[4] Steavenson claims brilliant results with the constant current.[5] With weakness of the sphincter one pole should be placed in the urethra, and the current passed in rapid alternations by means of the commutator. In reality, in this affection, as in so many others submitted to electricity, it is probably better to combine the two forms of electricity. The galvanic current should be used not as a "sedative," but to improve the nutrition of the sphincter muscle. Then—but coincidently—the muscle should be stimulated to contract by the faradic current, and thus exercised in the performance of its function. A daily *séance* is necessary, preferably at bed-time. Many other forms of treatment are adopted for enuresis, to which cursory reference may be found in the note.[6]

[1] Archiv. Pediat., 1889.
[2] British Med. Journ., 1886.
[3] Med. Record, June 13, 1891.
[4] Brit. Med. Journ., 1888.
[5] *Ibid.*, 1886.
[6] Williams recommends anodynes *per rectum*,—suppositories of morphine, belladonna, or atropine (Boston M. and S. Journ., 1886). Simmons claims that in boys the "specific cause is glandulo-præputial adhesions, which must be broken up" (Am. Journ. Obstet., 1880). Townsend advises circumcision (Arch. Pediat., 1887, vol. iv); so, also, Keating (Med. News, 1886, p. 57), who also treats a long list of causes, and administers belladonna or bromide or chloral. Clark (Arch. Pediat., 1889) passes the cold sound into the urethra, considering the enuresis of childhood as the analogue of spermatorrhœa in the adult.

ADHESIONS IN THE ACUTE AND CHRONIC INFLAMMATORY DISORDERS OF THE FEMALE PELVIS.

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At the very outset of our study of these conditions it must be recognized that we have to deal with a group of morbid conditions essentially different in their nature and tendencies toward progressive or retrograde changes, and equally different in the treatment which is indicated by each. The distinction of these varieties of adhesions calls for the most searching clinical study of each case, and, more than all, a careful discrimination of the pathological processes presented. Fortunately, abdominal surgery has placed in our hands a ready means of studying the subject in all its stages and variations, far more satisfactorily than if we had merely the post-mortem examination on which to depend, though the latter is often of extreme value where the former has not been possible. The farther our investigations in these directions are pushed, the more we shall become convinced of the necessity of distinguishing different stages, as well as varieties, of adhesions, and of recognizing the great value of such distinctions. We shall see that there are differences not alone in the permanent nature of certain forms, but quite as great differences in the tendency, on the one hand, to progressive change toward firmer organization, and, on the other hand, to disintegrations and disappearance of the morbid exudate.

It is, moreover, essential that we should recognize the conservatism of nature in providing, by means of exudation of plastic lymph and subsequent formation of organized adhesions, against dangers which must otherwise be of much greater moment. This principle, though by no means confined to the serous membranes, is in them developed to the highest degree, and its exemplification is seen in every part of the body. It is this process that causes the adhesion of the serous covering of the stomach or intestine beneath an ulceration to neighboring organs, and thus prevents a threatened perforation; or binds the spleen or lung to the adjoining structures to prevent the rupture of an abscess into the abdominal or pleural cavity; and we see the same provision active in the prevention of general infection of the abdominal cavity by agents entering at the open end of the Fallopian tube.

Accompanying each inflammatory attack of the pelvic serous membrane there is an exudation of plastic lymph. This exudation takes place in exact proportion to the severity of the inflammation, and its tendency to spread to the general abdominal cavity. The ready access

that would seem to be given to the entrance of infective matter to the abdominal cavity through the Fallopian tube is thus beautifully compensated for by the activity of the serous structures in throwing out an exudate which at once, and generally effectively, prevents further spread of the inflammatory processes. This barrier may begin and end about the peritoneal orifice of the tube and the ovary, resulting in a destruction of the fimbria and adhesion of the fimbriated end of the tube to the ovary, thus effectually preventing further ingress of infective material, but at the same time destroying the functional use of the tube. If the agent entering by the Fallopian tube (and this is almost universally the method of pelvic infection) is a virulent one, the rapidity of the spread and the somewhat different nature of the exudate lead to a more extensive dissemination in the pelvic cavity before any effective barrier may be established. In such a case the inflammation involves not alone the fimbriated extremity of the Fallopian tube and the ovary, but spreads to the broad ligament, the pelvic walls, or even farther. Should a greater effort be made and the inflammation tend to extend beyond the pelvic into the general abdominal cavity, the overhanging loops of intestines and the omentum become early involved, they are more or less firmly matted together by the exudate from their serous surfaces, and a limitation is thus given to the morbid process, generally confining it successfully to the pelvic cavity. Thus it will be seen that, according to the nature and the extent of the inflammatory disease, there may be established a variety of distortions, according as the brunt of the inflammation, with establishment of adhesions, has fallen in one place or another. From the situation of the tube and ovary on the posterior surface of the broad ligament, adhesions are most frequently met with behind the uterus, binding the ovary or tube to the rectum, the uterus, or the posterior pelvic wall; in case of more extensive disease the inflammatory changes may be found anteriorly as well, and thus adhesion to the bladder becomes established.

Formation of Inflammatory Adhesions.—When we come to the consideration of the morbid anatomy of the subject, we shall see at once the entire resemblance to similar processes in the other serous membranes, and we shall recognize that whatever differences exist in regard to the subsequent changes, the termination and the effect of treatment are to be explained by the peculiar anatomical arrangement and the difference in the irritant producing the inflammation.

Whenever a serous membrane is irritated, there is brought about a more or less extensive congestion, centring at the point of irritation, and leading very quickly to inflammatory exudation. The latter consists of the fluid element of the blood, together with a greater or less proportion of white corpuscles, and, from a chemical combination of substances contained in these, a considerable amount of fibrin. It is the peculiar nature of inflammations of all serous membranes to present

in their inflammatory exudations a notable quantity of fibrin, even in the case of purulent inflammations. This provision, we shall see, has much to do with the readiness with which adhesions are produced, and is doubtless intended to subserve this purpose. If, now, we examine a serous surface shortly after the onset of an acute inflammation, we shall find it covered with a coating of fibrin of yellowish-white or almost pure-white color. The distribution of this is effected by many local conditions of a mechanical nature. In the pericardium, the constant motion of one layer upon the other leads to an irregular massing of the fibrinous exudate, somewhat resembling a honey-comb. In situations where no such motions are found, the accumulations are more apt to be uniform. Microscopically there may be seen a reticulated fibrillar arrangement of the fibrin, or the latter may be present as masses of homogeneous or granular material not at all tending to fibrillation. Inclosed in the fibrin may be seen the out-wandered leucocytes, in greater or less abundance, and beneath all the serous membrane, with its dilated capillaries. On the surface of the membrane are seen the endothelial cells beginning to proliferate, as do also the more deeply lying connective-tissue cells. The newly-formed connective-tissue cells are recognized and clearly distinguished from the leucocytes by their larger size and the large, pale, vesicular nuclei. As the process of inflammation advances and organization begins, these large, oval cells elongate, becoming spindle-shaped, then stellate, and, finally, are transformed into fully-formed connective-tissue cells, whence the name *fibroblasts*, by which they are sometimes known. Coincidently with the new formation of connective-tissue cells there is absorption of the fibrinous net-work, which, having served the purpose of a skeleton for the organizing fibrous tissue, is no longer of use, and therefore becomes absorbed.

This, then, is the method in which the firm bands of connective-tissue adhesions are constructed, and by the mere preponderance of one or the other element in the process the different varieties of adhesions are produced. If the excitant is a violently-septic one, the exudation of leucocytes far exceeds that which is seen in ordinary inflammations, the fibrin produced is relatively scanty, and consequently, instead of firm adhesions and limitation of the process, soft, yellowish accumulations of fibrino-purulent material result, and wide-spread dissemination is apt to occur. If the irritant is slight, the exudation is more equally balanced in its various constituents, and the fibrin is likely to be absorbed before the regenerative processes in the underlying serous membrane have had an opportunity to institute new formation of connective tissue, the result being that the plastic exudate is more or less completely absorbed, and little is left beyond a localized thickening and induration of the diseased area. Finally, if the irritation be particularly violent or protracted, the masses of proliferating cells find time to push a way into the interstices of fibrin, to become fully organized, and thus to give rise to the dense,

fibrous bands so common in the pelvic cavity. It is thus seen that much depends upon the nature of the irritant, the condition of the tissues, with their proneness to proliferative changes, the activity of the circulation, and the tendency to absorption of the exudate.

As might be supposed, this matting together of the Fallopian tube, ovary, intestines, and omentum produces a tumor-mass of variable size, depending partly on the quantity of inflammatory lymph thrown out and partly on the thickening of the tissues themselves. A vaginal examination, therefore, not rarely discloses a tumor-mass out of all proportion to the amount of disease of the tube or ovary ; in other words, the tube or ovary, itself but slightly diseased, may be surrounded by such a quantity of lymph as to convey to the examining finger the impression that there is an amount of involvement of the tissues far greater than is actually the case. As the inflammation in such a case subsides, the mass will grow smaller and smaller, until finally, in certain cases, practically little or no enlargement can be detected by manual examination. This result is brought about, as we have seen, largely by resorption of the plastic exudate; but to a certain extent also, in cases where actual formation of connective-tissue adhesions has occurred, by the contraction of the latter; for it is a well-known characteristic of all newly-formed connective tissues thus to become condensed and more and more sclerotic. The former process, that of absorption, is always a beneficial one, and one which we should endeavor to promote ; the latter, on the other hand, though it may be conservative by completely obstructing further progress of an infective process, is more often fraught with serious consequences, and therefore our endeavor must be to guard against its occurrence. Of this more will be said later.

The gross appearances of pelvic adhesions differ with the varying conditions of cause and extent, and according as the favorable or unfavorable surroundings and health of the patient have influenced the course of the disease. In a mild and acute case there may be a certain amount of soft, yellowish-white lymph, which nature tends to re-absorb, and which, under proper conditions of rest and treatment, does so disappear without further difficulty. When the irritation is somewhat more intense and the conditions less favorable, the well-recognized, firm, white bands of adhesion are produced, and tend to remain permanently. This may be looked upon as the first and most important variety ; other forms will be seen to consist of a similar structure, to which have been added subsequent degenerative changes, causing differences in appearance. For example, in a virulent, septic infection through the Fallopian tube, unless general peritonitis and death occur, there may be a sudden outpouring of lymph in considerable quantity, which occludes the orifice of the tube and leads to pyosalpinx. The adhesions in such a case, at first healthy, subsequently undergo degenerative changes, become cheesy and friable, and we may find that variety of adhesion, so com-

monly met with, in which the tube and ovary are found imbedded in a mass of unhealthy material. In other cases of less virulent infection the same condition of investing adhesions, in which the ovary lies inclosed like a stone set in mortar, may be met with, the difference being that in these cases no such degenerative processes ensue, and the adhesion remains as dense and healthy tissue. In every case in which degenerative changes are absent and the process more or less prolonged, the adhesions become more and more dense as the fibrinous element is absorbed and fibrous tissue increases.

A somewhat peculiar form of adhesion is frequently seen, and from its very suggestive appearance has been called the "spider-web" or "cob-web" adhesion. It takes the form of a thin veil entirely surrounding the affected part much as would a spider's web, and has much the same appearance and structure. When traction is made upon any portion, it draws up into a cord, which resists considerable force. The conditions under which such a formation is presented are not altogether clear, but it is evidently due to more or less evenly distributed inflammatory process, and not to one spreading from a focal point.

Finally, we must carefully consider the stage of the particular process noted; for, as we have seen, the pathological conditions vary much at different stages of the inflammatory disease. In the very earliest there is marked tendency to exudation; somewhat later the exudation ceases and absorption becomes the ruling tendency, and at the same time, or a little later, proliferation and new formation, and, finally, contraction closes the scene. It is not difficult to see, then, that our procedures must differ widely, not alone with what we consider to be the kind and nature of the adhesion, but also with the stage of the process. It may not be easy to discriminate these various and varying conditions by external signs, but the influence of treatment will soon make clear any gain in the direction of resolution, and, with increased knowledge of the intimate pathology of the conditions, we may hope to become better able to diagnosticate and to apply appropriate treatment.

The question of the value of electricity in the treatment of the above-described abnormal processes must be preceded by some inquiry into the methods by which electricity does good in general, and in particular what influences it may bring to bear on the course of inflammation and organization. Of the two currents, faradic and galvanic, the latter alone merits consideration. The faradic current may possibly, at times, be of use by stimulating the general nutritive processes by action on the general organism, rather than locally, on diseased parts; but, in the great majority of cases, the galvanic current alone will be of avail. We have yet much to learn concerning the influence of this agent on the organism. The influence exerted on pain and the general tonic effect of electricity indicate the action of this agent on the nervous system, and its possibility of thus indirectly influencing morbid

processes. The effect on the circulation—the production of congestion and the stimulation of the absorbents—is a further aid, and the excitement of glandular action probably results from a combination of influences exerted upon the nervous system, the circulation, and the cellular metabolism itself. In all probability, the action of electricity in causing the absorption of abnormal deposits is, similarly, the result of a combination of the influences exerted on the circulatory, absorptive, and nutritive functions in the diseased area. Galvanic action has been divided into two sorts,—an electrolytic, in which the effect is due to the direct disintegration and separation of the constituent elements of an organized structure; and galvano-chemical, in which the results are achieved by the action of acids or alkalies liberated at either pole by electrolytic action. In the absorption of exudations and adhesions it is probably the former which is operative.

Electricity will be found to affect the different varieties and stages of adhesions in somewhat different manner. Naturally, in the early stages, when there is healthy, unorganized lymph, and nature has the greatest tendency to absorb, the greatest good may be expected from the treatment; but it is to be noted that the application of electricity must be subsequent to the completion of the process of exudation, lest, instead of promoting absorption, it stimulate the natural process and lead to excessive exudation. What is true of such recent inflammation and exudation is also true of certain chronic cases in which there are firm and organized bands, but in which an acute process superadded causes exudation of plastic lymph, with consequent enlargement of the pelvic mass. Under proper general treatment nature tends to remove the recent addition by absorption, and the application of electricity may hasten the process materially.

Later in the course of inflammation, when active organization has been established and cellular proliferation is marked, the electrical application is of much more doubtful value, and, indeed, it is possible that, by stimulating the abnormal overgrowth through the circulatory activity induced, it may contribute to the very result which it is intended to obviate. It is difficult to demonstrate these obscure questions in a convincing manner, but it would seem that early in the case stimulation increases absorption because the tendency of nature is to that end, while later stimulation promotes new formation because this has now come to be the ruling tendency.

We have thus far considered only the good to be achieved by promoting natural tendencies; but it is true, though to less extent, that we may institute changes not possible in the natural course of the pathological processes and of direct advantage in removing abnormal and injurious constrictions or deposits. Suppose that the organization of an adhesion has become complete and connective tissue has taken the place of plastic lymph. We have now to deal not with a pathological tissue,

but with abnormally-situated, though in every respect healthy, tissue. There is here no tendency on the part of nature to absorb and remove. If, then, such a mass is to be removed, it must be by some power altogether outside of nature,—supernatural,—whose impetus and fulfillment take origin from without. The evidence of many observers would indicate that we have in electricity an agent possessing such power to disintegrate and separate the elements of an organized tissue; but it must be admitted that such power is very limited, and we must admit that the claims in its favor have been far from temperate. The action exerted in these cases is a subtle one, of the nature of which we cannot at present form definite conceptions. Adhesions of this nature, to be affected at all, must be reached by some mysterious disintegrating power; for there is, on the one hand, no natural process tending to their removal, and, on the other hand, it cannot be by any cauterizing action, since the intervening structures between the diseased area and the electrode must necessarily first become destroyed.

Finally, in the class of adhesions in which secondary degenerative changes have occurred, infiltration with pus, or infection from the neighboring foci of inflammation, electricity is of no avail, any more than any other procedure, except operative treatment.

To speak dogmatically, we may say (1) that the electrical treatment finds its greatest usefulness in cases of simple, acute inflammation with exudation of plastic lymph; (2) that in chronic processes in which an acute inflammation with exudation has supervened, the latter is amenable to the treatment in just the same manner and to the same extent as a simple case without chronic disease; (3) that chronic, fully-organized adhesions are rarely benefited and may be deleteriously influenced; and (4) that friable, unhealthy, degenerated deposits are not at all benefited by this mode of treatment.

Application of the Treatment.—It may be premised that in every case the electrical treatment receives valuable and, at times, indispensable support from general management, such as rest in bed, functional rest, douches, counter-irritation, and the tampon. In the application of the electricity itself great care must be devoted to the strength of the current, the nature and condition of the electrodes and pads, and the effect of the treatment, as observed from time to time. The well-known tolerance of the mucous membranes of the genital organs makes it necessary to guard carefully against an excessive current, lest scars result from local destruction; and a current of too great strength may also influence unfavorably the processes of absorption in the diseased area. For the most part, a current of from 20 to 50 milliampères may be considered of the proper strength. The application is to be made by the negative pole, either intra-uterine or intra-vaginal. The positive pole, attached to a large, well-wetted pad, is applied to the anterior surface of the abdominal walls. The size of this pad is of considerable importance,

as the skin is much less tolerant of electrical application than is the mucous membrane, and, besides, it is not desired that the current should be received in concentration at this point. The length and frequency of the applications will be governed largely by the nature of the case and the subjective sensations produced. As a rule, the current may be applied from three to five minutes, and repeated two or three times a week.

It may be well briefly to refer to an action and use quite apart from the curative influence of electricity. It is possible that, in cases where the symptoms produced by adhesions—that is, the pain and discomfort—seem to be far out of proportion to the local trouble,—that is, in cases where the nervous system is called prominently into play,—the use of electricity may be highly beneficial as an agent to relieve this pain, without necessarily influencing the disease itself.

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